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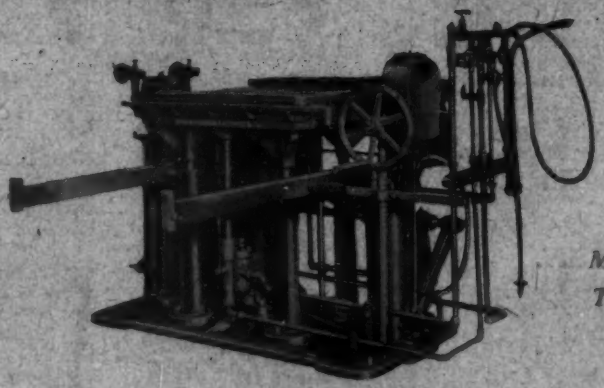

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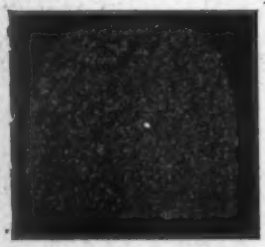
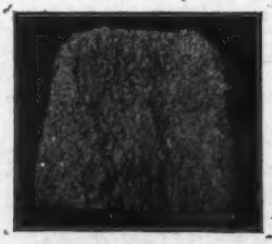
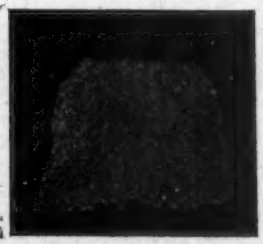

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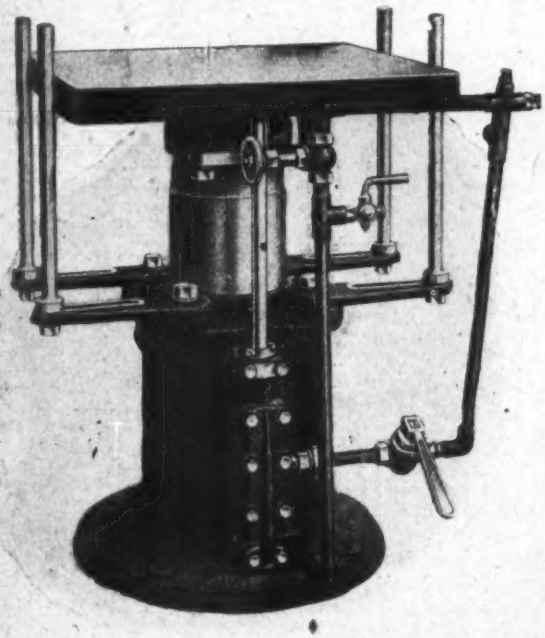

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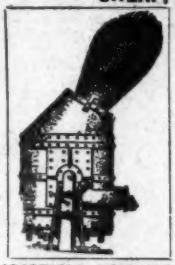

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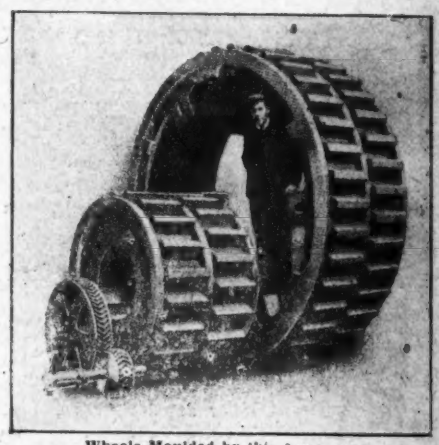

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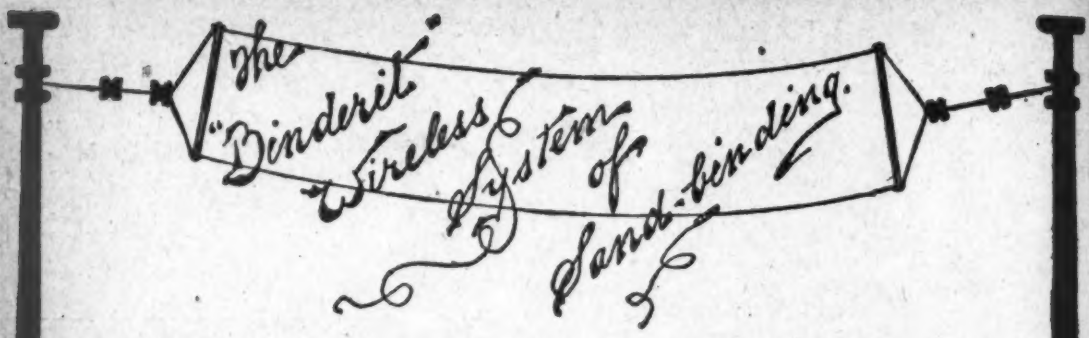

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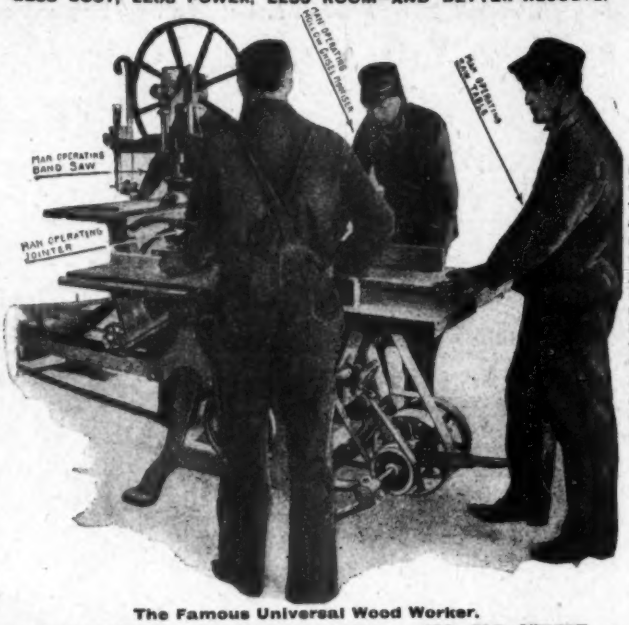

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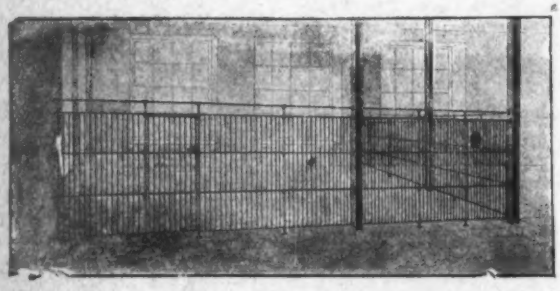

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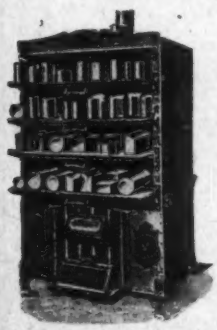

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The Foundry Trade Journal

AND PATTERN MAKER.

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Contents.

	PAGE
Notes and Comments	17
Influence of Gases in Iron and Steel	19
Use of Copper for Casting	28
Some Copper-Aluminium-Iron Alloys	29
Production of Aluminium Castings	31
Testing Refractory Fireclays	36
Some Experiences in Steel-Foundry Practice	37
Aluminium Alloys	42
Machine Moulding	43
Gronwall-Dixon Electric Melting and Refining Furnace	45
Non-Ferrous Notes	47
Trade Talk	48
Deaths	49
Personal	50
Application for Patents	50
New Companies	52

Forthcoming Events.

JANUARY 12.

British Foundrymen's Association: London Branch.—Repetition Work and Machine Moulding," by A. R. Bartlett (Erith).

JANUARY 13.

British Foundrymen's Association: Scottish Branch.—"Cores: Materials and Comparative Costs," by A. Naylor.

British Foundrymen's Association: Lancashire Branch.—"Foundry Trade After the War," by M. Disley.

JANUARY 17.

British Foundrymen's Association: Sheffield Branch.—"The Scientific Study of Refractory Materials," by Dr. Fearnsides.

JANUARY 26.

British Foundrymen's Association: East Midlands Branch (at Leicester).—"Repetition Work and Machine Moulding," by A. R. Bartlett (Erith).

JANUARY 27.

British Foundrymen's Association: Birmingham Branch.—"Mechanical Tests in the Foundry," by F. J. Cook (West Bromwich).

British Foundrymen's Association: Newcastle Branch.—Official visit by the President.

NOTES AND COMMENTS.

The Past Year.

The year of 1916 has been one of continued abnormal conditions, accentuating the developments of industry which characterised the previous year of war. Government control has been greatly extended, labour supplies denuded, materials commandeered or restricted in supply, and many other essential war conditions established. It is a tribute to the adaptability of the national temperament that all this has been done so smoothly. Certainly we have, during the past year, come much nearer to the position of all energies being concentrated on winning the war, but to say that there is no reserve still to be called upon would be wrong. However, we appear to have met the requirements up to the present to such an extent that the outlook for Great Britain and her Allies has changed greatly for the better; for the present hopeful position has been very largely due to the magnificent effort put forward by all concerned in our great iron and steel industries. It has become more and more evident as the war has proceeded that the ultimate victory will be won by the side which is able to secure and bring to bear in the field the preponderating weight of artillery and munitions. It is in the workshops and arsenals of Britain that victory is being organised, and through whose continual efforts the final downfall of the enemy will be assured.

Britain is having to supply not only her own Army, but also, to a very great extent, the armies of her Allies, and to keep all adequately fed is a task which taxes, and must continue to tax, the utmost energies of which we are capable. But there is also the Fleet to be considered, with its enormous demands on the skill and the resources of our people, and second only to the Fleet are the needs of the mercantile marine, which call loudly for attention if we are to neutralise the menace of the enemy submarines, and to assure sufficient food for the population. To meet these manifold requirements, the iron and steel industries have had to labour continuously day and night; huge extensions of existing plant have had to be made, and new works laid down on an unprecedented scale in all parts of the country. But this work of extension has had to be carried out in the midst of almost insuperable difficulties, due to the lack of labour and material, and the full effect on the output of munitions will not be felt for some time to come. Nevertheless, the great progress which has been already achieved enables us to look forward with confidence to our ability to meet all requirements in the coming Spring campaign.

National Physical Laboratory.

In a recent address the Director of the National Physical Laboratory dwelt on the important part played by that institution in assisting the progress of the past ten or fifteen years. He pointed out that since its establishment the Laboratory had

done and is doing most valuable work for our industries and for the Government, and might have done much more had it been endowed with anything like the annual subvention of nearly £100,000 which the American Bureau of Standards receives from the United States Government. We have only to refer to the contributions which it has made in recent years to foundry metallurgy to realise its value, and this has been relatively a small portion of its work.

The National Physical Laboratory is controlled by the President and Council of the Royal Society, but that control is exercised through a general board and executive committee containing representatives appointed by six of the great technical societies; at least half of the unofficial members of the executive committee must be selected from the representatives of these technical societies. The Royal Society receives from the Government the sum of £7,000 annually towards the cost of the Laboratory. In the year before the war the actual expenditure was nearly £41,000, and practically the whole of the difference between these sums had to be raised as payment for work done; towards this an amount of about £5,000 was received from the Government for researches in aeronautics. The Government also pays for tests and investigations carried out for their various Departments.

The financial responsibility for the Laboratory rests on the Royal Society, but as a matter of fact the working of the Laboratory has resulted in a small balance—now amounting to some £4,500—which constitutes its working capital. To run a business of £40,000 a year on a working capital of £4,500, as Dr. Glazebrook pointed out, is a hazardous procedure. The fact is that the whole financial position needs overhauling. Before the war the German institutions in and near Berlin, which covered approximately the same ground as the Laboratory, had an income of about £70,000, while that of the Bureau of Standards of America was well over £100,000. In both these cases the Governments are responsible for the whole expenditure, and take the receipts from fees. The Laboratory owes much to private donors. During the first fifteen years of its existence the grants from the Treasury for capital expenditure amounted to £59,000; during the same period nearly £56,000 was received in donations and grants from various individuals and institutions, while nearly £20,000 was defrayed out of income. Towards the annual expenditure in the same time £80,500 was received from the Treasury, £166,000 in fees, while £15,000 came from grants from bodies like the Institutions of Civil and Mechanical Engineers, the Iron and Steel Institute, the Institution of Naval Architects, and from private individuals. The total expenditure on aeronautical research defrayed by Government amounted to some £33,000. These figures carry the expenditure up to March 31, 1914. Since the commencement of the war the whole Laboratory has been given up to war work.

The Laboratory is situated at Bushy House, Teddington, and to-day it comprises eight large buildings. It is organised in four main departments, each with its superintendent, which are :—(1) Physics. (2) Engineering. (3) Metallurgy. (4) The William Froude National Tank.

Government Assistance in Research Work.

In view of the foregoing it is interesting to refer to an official statement issued last month by the Board of Education, which announces that a separate department of scientific and industrial research for Great Britain and Ireland is to be established under the Lord President of the Council, with the President of the Board of Education as Vice-President.

The Board of Inland Revenue have decided, with the approval of the Chancellor of the Exchequer, that no objection shall be offered by their surveyors of taxes to the allowance as a working expense for income-tax purposes of contributions by traders to industrial associations which may be formed for the sole purpose of scientific research for the benefit of the various trades, and that allowance would be equally applicable as regards traders' contributions specifically earmarked for the sole purpose of the Research Section of an adapted existing Association. In both cases the allowance would be subject to certain conditions, e.g., the Association or the Research Section to be under Government supervision and the trader's contribution to be an out-and-out payment made from his trade profits and giving him no proprietary interest in the property of the association, etc.

In order to enable the Department to hold the new fund and any other money or property for research purposes, a Royal Charter has been granted to the official members of the Committee of the Privy Council for Scientific and Industrial Research under the title of the "Imperial Trust for the Encouragement of Scientific and Industrial Research." The Trust is empowered to accept, hold and dispose of money or other personal property in furtherance of the object for which it has been established, including sums voted by Parliament to that end. The Trust can take and hold land, and can accept any trusts, whether subject to special conditions or not, in furtherance of the said objects.

Mr. H. Frank Heath, C.B., has been appointed Permanent Secretary of the new Department, to whom all correspondence should be addressed at Department of Scientific and Industrial Research, Great George Street, Westminster, S.W.

In the course of a reply to a deputation from the Joint Board of Scientific Societies last month, Lord Crewe (Lord President of the Privy Council and President of the Committee of the Privy Council on Scientific and Industrial Research), stated that, amongst other assistance, the Government proposed to vote annually money for purposes, such, for instance, as those cases in which an individual research worker needed a grant in order to enable him to get on with the problem he had in hand. There were also some scientific societies which stood in need from time to time of assistance to enable them to carry on research work, and such assistance would be given where necessary. As to the finances of the National Physical Laboratory, these would be given the most careful consideration by the Advisory Committee, because the value of the work done at Bushy was fully recognised. Closely related to the question of industrial research was technical school training, and the conclusion had been arrived at that the present regulations under which technical schools received public money, apart from university institutions, were not up to date for modern conditions. It was therefore proposed to discuss with the local authorities concerned certain new draft regulations. Further, the Government had decided that special increases would be made to the estimates of the Board of Education for assisting local authorities managing technical schools. In addition, important arrangements would be made for the training of technical teachers and for granting of scholarships, in order to carry to the universities selected industrial students.

Influence of Gases in Iron and Steel.

At a meeting of the Birmingham Branch of the British Foundrymen's Association held on November 27, Mr. J. Shaw (President of the Branch), in the chair, a lecture was delivered by Mr. J. E. Fletcher, M.I.M.E., of Dudley, on "The Influence of Gases in Iron and Steel."

The Branch-President, in opening the meeting, extended a welcome to Mr J. Ellis (President of the Parent Association), who was there in his official capacity.

Mr. J. Ellis complimented the officers of the Branch upon the maintenance of its work, which was of the first importance, as the Association, particularly at the present time, mainly existed through its Branches. He earnestly appealed to the members to see that each did his share in realising the aims of the British Foundrymen's Association, and seeking to extend its membership.

Mr. Fletcher then proceeded to deliver his lecture as follows, showing also an excellent series of limelight views :—

The precise constituency of molten cast-iron and steel is to a large extent unknown. That it must contain in solution iron, carbon, silicon, manganese, phosphorus and sulphur we know; but exactly how these metals and metalloids occur when in the liquid state we cannot yet with absolute certainty define.

Our experimental evidence is gained from chemical analysis and microscopic examination from the solid material alone, but research has revealed the fact that the above-named elements are largely present combined with one another, the constituents carbon and iron alone existing in the free state. It may further be remarked that the two latter elements carbon and iron are usually found in both the free and combined states in all carbon-iron alloys, excepting perhaps that free carbon is not found in low-carbon steels.

No apology is needed for urging the claims for the clearer view of these now well-known facts, and, seeing that there is no explanation to the things which happen to the structure of iron and steel during the melting and solidifying periods except through the medium of the chemistry and metallurgy of the materials concerned, it is obvious that the scientific view is the practical one.

It is established that the elements which are found combined in commercial iron and steel are of the following order :—

(1) Iron and carbon are combined as carbide of iron (F_3C).

(2) Iron and silicon are combined as silicide of iron (Fe_2Si or FeSi).

(3) Iron and phosphorus are combined as phosphide of iron (Fe_2P).

(4) Iron and sulphur are combined as sulphide of iron (FeS).

(5) Manganese and carbon are combined as manganese carbide (Mn_3C).

(6) Manganese and sulphur are combined as manganese sulphide (MnS).

Taking two illustrations representative of iron and steel castings, the chemical and constitutional analyses can be expressed as follows :—

Steel Casting.

	Per ce		Per cent.
Carbon	0.32	Carbide of iron	4.80
Manganese	0.60	Carbide of manganese	0.56
Silicon	0.35	Silicide of iron	1.75
Phosphorus	0.08	Phosphide of iron	0.43
Sulphur	0.05	Sulphide of manganese	0.13
Iron	98.60	Free iron	92.33

Cast Iron.

	Per cent.		Per cent.
Carbon (graphitic)	3.10	Graphite	3.10
Carbon (combined)	0.50	Iron carbide	7.50
Silicon	2.50	Iron silicide	12.50
Manganese	0.60	Manganese carbide	0.40
Phosphorus	0 70	Iron phosphide	3.85
Sulphur	0.10	Manganese sulphide	0.24
Iron	92.50	Free iron	72.41

But, although these compounds have been separated by means of chemical analysis, the microscope has revealed other facts, and the recording pyrometer by tracing the characteristic curve of cooling of the metal has brought out the fact that during the freezing and cooling of cast iron or steel, certain constituents of these alloys solidify first, and are followed by others, in ordered succession.

In cast iron, for example, the microscope reveals a constituent which is a mechanical mixture of iron carbide and iron, known as the eutectic, containing 4.3 per cent. of carbon, and also another somewhat similar constituent containing 0.9 per cent. of carbon, known as the eutectoid pearlite. Such considerations enable us to express the constitutional analysis of the cast iron in another form thus :—

	Per cent.	
Graphitic carbon	3.10	Analysis in cold state after slowly cooling down from the melting point.
Phosphide eutectic	10.00	
Eutectoid pearlite (containing Mn_3C.)	33.30	
Silico-ferrite (containing free iron)	40.86	
Silicide of iron	12.50	

Now, such a metal as the above when quenched from the molten state in iced brine is, when examined under the microscope, practically free from graphitic carbon. Chemical analysis shows that the carbon is in the combined state, and the constitutional analysis then becomes :—

	Per cent.	
Eutectic containing 4.3% carbon	77.26	Analysis after quenching from molten state.
Phosphide eutectic containing carbon 1.92%, iron 91.19%, phosphorus 6.89%	10.00	
Manganese sulphide	0.24	
Silico-ferrite	12.50	

This analysis is important in its chief characteristics, for it is the nearest evidence we have concerning the constituency of molten iron. The argument is that if quenching fixes the constituents present at the time of so doing then the microscopic representation of the quenched alloy must be closely that of the virgin molten metal. The author has made many such experiments in the way of quenching various carbon iron and other alloys from the molten state, and cannot tear himself away from the conclusion that there are definite structures even in the liquid metal itself. The two eutectics mentioned in the foregoing quenched sample analysis very possibly have their structures defined whilst in their molten condition, though the silico-ferrite crystallites may not, seeing that they grow at the expense of the iron or ferrite in the eutectics.

It is unconventional perhaps to consider eutectics as existing above the temperatures of their melting points, but it is certain that the 4.3 per cent. carbon eutectic can be superheated to 1,500 C. (the melting point of iron), and on being quenched will still reveal under the microscope its characteristic stratified honeycomb structure. The silico-ferrite crystallites are in such circumstances small, but of the characteristic fir-tree or dendritic structure. On measuring up the micrographic areas the relative volumes of eutectic and silico-iron crystals are true to the analysis given.

It may be that there are liquid iron crystals, as Quincke and Schenk have surmised, in a liquid matrix of eutectic composition, and that these crystal forms and the eutectic structure are preserved by sufficiently brisk quenching from the molten condition. Gases are imprisoned or dissolved in all molten metals, and in cast-iron and other eutectic-containing metals or alloys these gases are very probably the formative or directive element in the growth of the honeycomb-like structure of the primary eutectic.

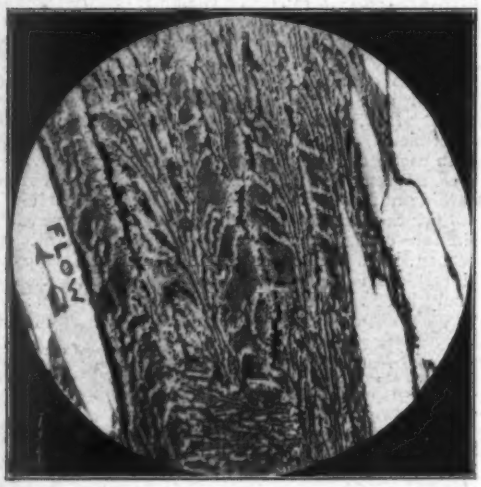


FIG. 1.

The flow-line structure always having a direction towards the upper and hotter portions of the freezing mass of a eutectic ingot give the impression of fine gas streams set in motion by convectional forces, just as the streams of steam bubbles are given convectional flow in a boiler. (Fig. 1.) It may be that the primary gas streams in flowing through the semi-liquid carbide of iron plate-like crystals make the paths through which the ferrite (more or less carburised) enters and freezes, such freezing action being immediately afterwards followed by that of the carbide.

In Fig. 2 is shown a pure eutectic iron which has been quenched from the melting point. Fig. 3 shows the same metal quenched in iced brine after superheating to 1,500 C. (370 above its melting point). Fig. 4 illustrates a cast iron of similar analysis to the typical one, quenched from above the melting point, whilst Fig. 5 shows the same iron when slowly cooled to room temperature.

Now the structure of a cast iron must have some relation to the primary one it received in the blast furnace. The iron was reduced there from the ores, and descending became carburised by contact with the coke and carbon-monoxide gas, the latter being the chief carbonising agent. Finding its way to the hot zone of the boshes it has absorbed sufficient carbon to make a fusible alloy, and in such state it flows down into the hearth, having a composition approximately that of the eutectic (4.3 per cent. carbon), and having by that time probably a distinctive structure. If this eutectic alloy has not absorbed enough carbon to become the true 4.3 per cent. carbon eutectic, or if it becomes Bessemerised by the blast, then iron crystals are thrown into the eutectic, and the structure has then the constituency of iron crystals plus eutectic.

These crystals become more or less carburised, but though they grow during the slow cooling in the casting bed they preserve their entity, and possibly do so to the end of their life, when they may be found as part of the crystalline structure of a mild steel. Let us briefly consider the changes which take place during the reduction of the ore in the blast furnaces and onwards to the completion of the alloying period in the hearth of same. Whilst the ores are being reduced the oxides of silicon, manganese and phosphorus remain unaffected. During this period the iron oxides are attacked by the carbon-monoxide gas which is the principal reducing agent, as it is the chief carburising medium. Now *each particle* of iron oxide must come into contact with the reducing gas or with the carbon of the coke. The latter contact cannot be so great a factor as is sometimes considered, seeing that the coke descends in large measure unbroken into the hearth.

It can be shown that when the reduction of the ore is accomplished by means of the gas CO, then about 1.2 lbs. of the gas CO_2 are set free for each pound of iron reduced. At the temperature of such reduction, say, at 1,400 deg. F., the volume of the gas is about three times its bulk at 60 deg. F.; hence, it will be possible to prove that each pound of iron oxide Fe_2O_3 in the ore when attacked by the gas CO liberates over 5,000 times its volume as CO_2 gas. It is not, therefore, difficult to imagine as a result of such gaseous action the porous nature of the reduced iron, aptly called spongy. This may be called the first stage in the gas-absorbing tendency of iron, for it is impossible to reasonably conclude that within the meshes of the spongy iron there can be freedom from gas imprisonment.

The presence of hydrogen in the gases imprisoned by the above section is readily understood when we consider that the gases which attack the ores are a mixture of (1) moisture evaporated from the blast, ores, flux and fuel; (2) air; (3) carbon-dioxide gas, CO_2, from the decomposition of the limestone, and

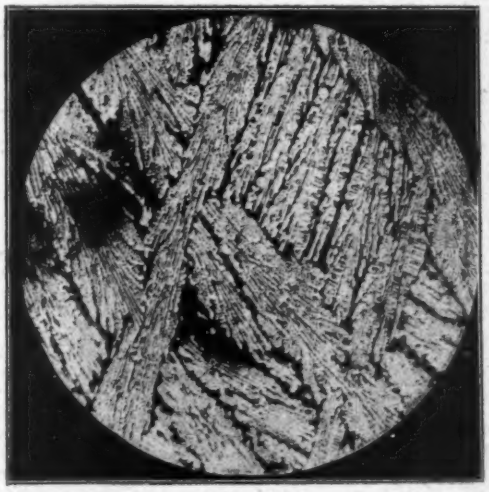


FIG. 2.

(4) carbon-monoxide gas, CO, produced by the part combustion of the coke and liberated by the ore which is partly reduced by direct contact with the carbon of the coke.

Let us further look at the reduced iron as it meets the stream of CO gas, and as it further

comes into contact with the carbon of the coke. This contact brings about the cementation or carburisation of the spongy iron.

Thus $4Fe+CO=Fe_3C+FeO$ (1)
and $FeO+C=Fe+CO$ (2)
also $3Fe+C=Fe_3C$ (3)

Dr. Stead and others have shown that the carburisation of iron by blast-furnace gas is possible, the CO present therein being the medium. Here, again, we see the influence of gas in the history of the evolution of pig-iron.

During the carburisation of the spongy iron before the hearth is reached it can be shown that gases having from 1,200 to 1,500 times the bulk of the iron operate upon it; most of it is absorbed in carburising the iron, Fe_3C (iron carbide) being formed, but a considerable portion is liberated, and it is certain that some of it is occluded or imprisoned within the iron mass. This is the second stage in the gas-absorbing tendency of iron.

When the carburised metal reaches the blast-furnace hearth it is accompanied by the newly-formed slags. It is in the hearth area where the alloying with the metalloids silicon, phosphorus, manganese takes place. These elements enter the iron by way of the slag, and do so by expelling a certain portion of the iron carbide from the molten almost eutectic iron. It is impossible to convey this phenomenon except by chemical formulæ. Thus silicon enters the pig-iron according to the reactions:—

$$Fe_3C+SiO_2=Fe_2Si+FeO+CO$$
or $$2Fe_3C+SiO_2=Fe_2Si+4Fe+2CO.$$

The silica of the slag attacks the iron carbide in the molten iron; silicide of iron is formed, liberating iron crystals and the gas CO escapes. Approximately, in 100 lbs. of pig-iron containing 1 per cent. of silicon, 2 lbs. of the gas CO are set free during the absorption of the silicon from the slag.

When manganese enters the pig-iron the carbide Mn_3C is formed. Here, for every per cent. of

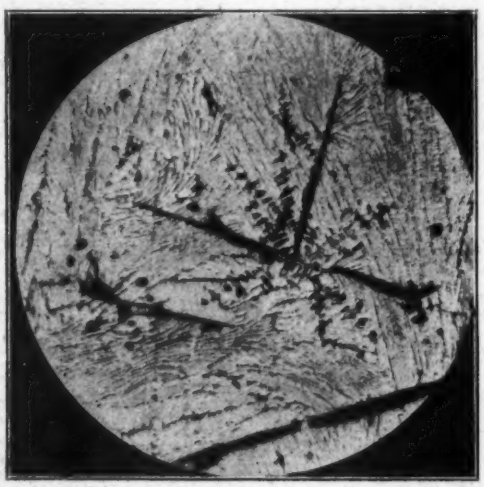


Fig. 3.

manganese absorbed by the metal from the slag, about 0.5 lb. of CO gas is liberated per 100 lbs. of pig-iron produced. The reaction is here of the kind:

$$3MnO+Fe_3C=Mn_3C+3Fe+CO.$$

Similiarly phosphorus is absorbed by the carburised metal, the carbide Fe_3C being exchanged for the phosphide Fe_3P, the phosphoric acid P_2O_5 being the object attacked by the carbon of the carbide and CO gas is set free. Here about 2¼ lbs. of CO gas are liberated, when 1 per cent. of phosphorus passes into 100 lbs. of pig-iron. In a normal No. 3 Staffordshire part-mine foundry pig-iron I

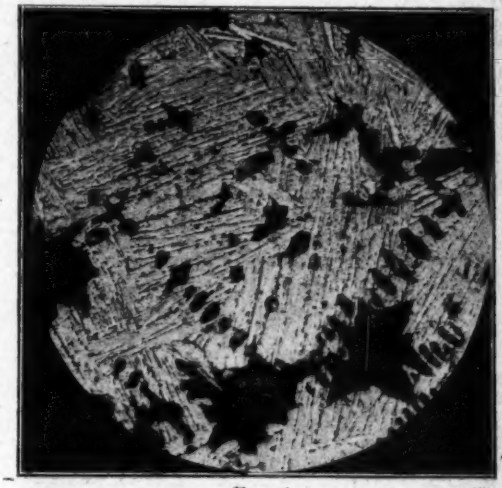


Fig. 4.

have estimated that about 6½ lbs. of CO gas are liberated during the alloying of Si, Mn, and P in the hearth. This, at 1,500 deg. C., is equivalent to about 1,200 times the volume of the molten iron acted upon.

Summarising the above we see that the gas CO plays a very important part in (*a*) reduction of the ores, (*b*) carburisation of the spongy iron, and (*c*) alloying of the molten iron in the hearth with Si, Mn and P.

In process (*a*) the gases liberated or used are about 5,000 times the volume of the oxide of iron in the ore; in process (*b*) they are about 1,200 to 1,500 times the volume of spongy iron, and in process (*c*) they are about 1,200 times the volume of liquid iron.

I have further estimated that during the melting and conversion of pig-iron into steel in the open-hearth steel process, the gas CO being again the chief factor in the reduction of the metalloids Si, Mn and P, there is liberated through the slag gas CO equal to:—(1) During melting period about 30 times the pig-iron volume; (2) during boiling period about 50 times the pig-iron volume; (3) during finishing period about 10 times the pig-iron volume.

In such process the greatest gas evolution is where the liquid metal pressure is least, viz., near the surface of the bath. If the melting and reduction or elimination of the metalloids is carried out at too high a temperature the slags become highly ferrous in characer, and the gas evolved during the boiling period is greater in volume; hence the boil is vigorous and wild in character, the resulting metal being high in occluded gases, unless means are taken to quieten or kill it in the finishing process, or by means of deoxidising additions such as aluminium, silicon or titanium. The tendency is towards a thick slag through whic the gases must escape whenever the conversion

temperature is excessive in the presence of an oxidising atmosphere.

It is interesting and useful to observe, in passing, how slags have an influence on the gas problem. It has already been pointed out that in the hearth of the blast furnace, where the metal lies fluid under the blanket of slag, the influence of temperature causes an interaction between the carbon in the iron and the silicon and phosphorus in the slag. The silicon and phosphorus under certain temperature and slag analysis conditions enter

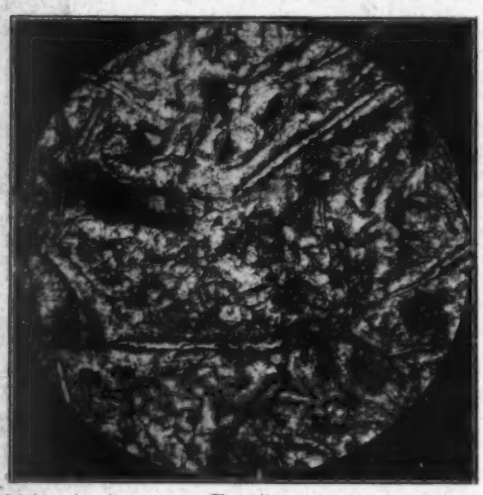


FIG. 5.

the slag, and the gas CO escapes. Now, if the slag is thick and viscous, it is resistant to the gas escape, and the tendency is then for the iron to retain some of the gas. Thus, certain highly basic slags, when operating in cool-working furnaces, produce pig-irons whose appearance at once indicates the gassy nature of the fluid metal, the upper surface of the pigs being covered with blow holes. In both the blast furnace and open-hearth steel processes it is reasonable to conclude that a not inconsiderable portion of the gases operating during the *reduction* and conversion periods must become imprisoned within the metal structure. That such gases do become so occluded has been proved, and several metallurgists, notably Troost, Hautefeuille, Stead and Baker, have shown the composition and the amount liberated under certain conditions. The more recent experiments have shown that when pig-iron or steel is heated to 900 deg. C. and over, and the gases exhausted *in vacuo*, these are found to consist of hydrogen and carbon monoxide in almost equal volumes, but little nitrogen being present. Even alloy steels yield under the same high-temperature heating *in vacuo* similar gas analysis, viz., CO 45 to 50 per cent., H_2 50 to 55 per cent., recent research by Roylston and Donaldson having proved that the different metalloids present influenced the amount of the occluded gases.

Now, as gases expand considerably under the influence of such temperatures as prevail in iron smelting and refining operation, it will readily be seen that in the reduction, carburisation and alloying of the metalloids in the blast-furnace hearth the use of specially high-temperature smelting yields metal containing large quantities of occluded gas. In the cupola, air furnace or steel-melting furnace, where a certain amount of decarburisation and removal of silicon, phosphorus, managanese and sulphur takes place, it will be found that such removal of metalloids is brought about by the influence of the gas CO which in the process escapes into the slag and away.

(1) Thus in the air-furnace reaction, producing a lower-carbon cast iron, and in the steel-melting furnace the operation of carbon elimination is expressed by the equation :—$Fe_3C+O=3Fe+CO$. (2) The action of desiliconising in the cupola, air and steel furnace is thus expressed :—$Fe_2Si+2O=SiO_2+2Fe$. (3) The action of manganese elimination is expressed thus :—$Mn_2C+4O=3MnO+CO$. (4) The action of dephosphorisation is as follows :—$2Fe_3P+5O=P_2O_5+6Fe$.

In all the above operations the tendency (where the temperatures are in excess of those necessary for the reactions as given to occur) is for the oxides FeO or Fe_2O_3 to form first, these being attacked later by the carbon present, iron being liberated thus :—$FeO+C=Fe+CO$.

Such actions undoubtedly occur because the low temperatures necessary to oxidise the Si, Mn and P are always exceeded in actual practice, and ferrous slags are produced. Hence the gas CO always plays a part in the cupola, air-furnace and steel-melting actions. Excess temperature produces gas evolution which must enter the metal being acted upon to a greater or less extent.

The foregoing matter concerns more especially the theoretical explanation of the presence of gases in metals, such as cast iron and steel. Without such it is impossible to comprehend the part gases play practically in the evolution of the finished product.

The fracture of the metals does to the practised eye convey a great deal, and an examination of the upper surface of cast iron as it runs into the

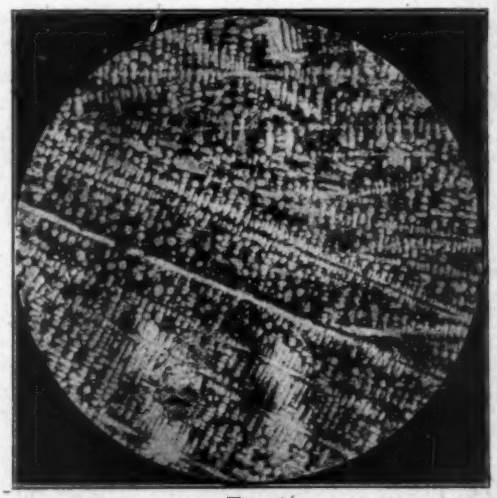


FIG. 6.

pig-bed and of its cooled exterior is often an index to the effect of carbon, phosphorus and silicon. But the microscope is an invaluable and indispensable aid to the structure as is the recording pyrometer to the behaviour of the metal from its freezing point to the cold state. The use of the microscope, however, is an acquired art which requires long practice, and it cannot be too strongly urged that the effects of temperature, slow and rapid cooling,

the influence of mass on the structure of cast iron and steel of varying analysis must be studied closely before the microscope can yield really useful results. Similarly the cooling curves taken from small samples may be misleading. Thus two small ingots of cast iron may be made from the same pig, one being carefully protected from oxidation during melting, the other free to surface oxidation. If such samples are melted and superheated to temperatures much in excess of their actual fusion points the cooling or freezing-point curves will be dissimilar though there may be but little difference in the two analyses.

A low-silicon pig-iron was so melted and the cooling curves taken were as shown in Fig. 7. The jog in the curve A here indicates the fact that the iron oxide formed during the superheating of the sample had partially oxidised the carbon of the carbide, and had caused a separation of free iron crystals from the eutectic. This separation takes place at a higher temperature than that of the normal pig-iron, and is shown by the jog in the curve at point P.

In the study of the gas influence the principal use of the microscope is in tracing the difference in crystalline structure between the outer rapidly cooled and the inner slowly cooled zones of a casting, and if the cooling curves are taken simultaneously at each of these zones then in many cases the difference in the freezing behaviour with its action on the phenomena of shrinkage and contraction may be observed. Thus in a high-phosphorus iron there is considerable segregation of the phosphorus (as phosphide eutectic) towards the centre of the casting mass, and it is not unusual to find this reflected in the cooling curves taken from the exterior and the interior of the casting. The reason is, of course, that the higher phosphorus content of the interior lowers the freezing temperature there.

The mechanism of the freezing or solidification of iron and steel is a most fascinating study, and this can only be attacked by the aid of the microscope, bringing to our help the practical observations of long foundry experience.

Just previous to the commencement of freezing of

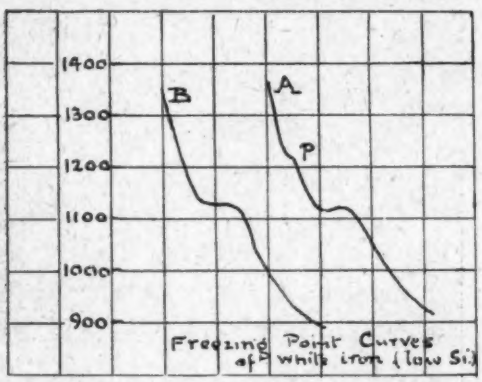


FIG. 7.

cast iron or steel the liquid metal may be conceived to consist of an agglomeration of liquid particles or crystals of iron more or less carburized, silicide and phosphide of iron, carbides of iron and manganese, and of the sulphides of iron and manganese.

First there separates out and freezes at the mould surface, and at right angles to it, crystallites, or fir-tree shaped dendrites of partly carburised iron in the midst of a mother liquor which is made up of carbide, phosphide, silicide and sulphide of iron and of manganese carbide and sulphide (Fig 6). Almost immediately afterwards the silicide of iron freezes around the iron crystallites. These crystallites as they freeze eject their occluded gases which they (as liquid crystals per-

FIG. 8.

haps) originally contained, into the mother liquor, or eutectic. As the iron (or silico-iron) crystals elongate and grow laterally the gases are driven inwards, producing a flow of the mother liquor in that direction, towards the hot and fluid mass centre. The volume of any such partially frozen portion of the metal is then always :—

Primary Crystals + Mother Liquor + Ejected Gases
A B C

As A increases B decreases, whilst C simultaneously decreases. In cast iron the mother liquor B contains the segregates, slag oxide and sulphide particles, together with the graphite flakes or grains which escape with the gases into the hot fluid portions, which when frozen contain the highest percentages of these impurities. The gases thus liberated travel to these hot zones in the casting which are the last to freeze, and if there is no way of escape to the surface of the ingot or casting, or by way of the riser, then gas cavities or pipes must occur.

The function of feeding is therefore evident. As freezing progresses from the outside of a casting inwards, driving the gases thither, unless a path is kept clear, and hot fluid metal can take the place of the gas bubbles or streams, gas cavities or sponginess must remain.

In a Paper on this subject given before the Staffordshire Iron and Steel Institute in 1907 I first pointed out how the crystallisation is influenced by the gas streams. Thus in a square ingot the crystals forming at the surfaces of the chill mould start in their career of freezing at right angles to these cooling surfaces. The crystals forming at the corners must meet one another in their growth, and there is produced at each corner of the ingot a plane of weakness. At the bottom of the

mould there grow crystals which in freezing meet the crystals growing from the sides, and there is formed a pyramid whose surfaces are planes of weakness. Along these planes the ejected gases travel together with the segregates and slag particles, eventually reaching the central axis of the ingot, through which they ascend to the ingot top. The action of the gases which escape into the

FIG. 9.

mother liquor when the primary crystallites begin to form and grow is much more important than has been generally considered. The natural tendency of the primary crystallites to grow at right angles to the mould side or chill surface is disturbed in many cases by the influence of the gas streams, whose direction is always towards the point of easiest escape. This direction of flow is, of course, towards the hot fluid mass centres, and naturally upwards. In a series of small cast-iron ingots of taper form the direction of the gas streams and of the primary crystals is clearly seen in the fractured surface as illustrated in Figs. 8 and 9. This surface when polished and etched was examined under the microscope, and it was proved that the curved lines of the fractured surface corresponded to the directions of the long axes of the primary crystallites, and to those of the plate-like crystals of eutectic. Fig. 10 illustrates the manner in which the minute gas bubbles are imprisoned between the arms of the fir-tree crystallites in an alloy steel well known for its viscous character during the freezing stage.

When there is no exit at the top of a casting whereby the liberated gases can escape these will flow towards the vent wherever this is placed, and I have in one case observed a downward flow. Here a small ingot was run from the bottom through a trumpet runner as commonly used in the casting of steel ingots in closed top moulds. The mould was first filled with molten slag, which was immediately afterwards displaced by molten white cast iron. The result of the experiment is shown in Fig. 11, the gas paths being downwards. In cast-iron ingots the phosphide of iron, and the sulphides, together with the graphite liberated, travel along the planes of weakness, being assisted thither by the propelling action of the escaping gases. The study of the freezing of the metal in a simple ingot is very valuable, as from this one can turn to more intricate cast forms and get explanations to many of the mysterious happenings and the reasons for common failure.

Messrs. A. W. and H. Brearley in a recent Paper on ingots, when dealing with the normal freezing of the primary crystals in steel, accounted for the central pipe or cavity by concluding that as the crystals and mother liquor freeze from the ingot exterior to the interior, the shrinkage of such crystals leaves a shrinkage or contraction cavity in the axis of the ingot. The lower part of the ingot cavity, they argued, becomes filled with hot metal from the upper portion or head, the more effectively if the head is kept hot by means of a sand top or of a heated one, as in Sir Robert Hadfield's method. Now this plausible explanation does not really meet the case, and to understand why the pipe in the top of an ingot of well-melted or killed steel is of the normal shape, one must better define what shrinkage really is.

Imagine a square ingot of parallel sides. The freezing commences at the outer envelope, the crystals as they form growing normally towards the ingot centre. Brearley says that the crystals as they freeze grow in the mother liquor, and at the expense of the same. They at length meet one another at the ingot centre, and, on cooling, contract or shrink, leaving a cavity, which, in the bottom portion of the ingot, becomes filled or fed with liquid metal from the upper portion. Now, it must be taken for granted that the crystal shrinkage is uniform throughout the metal mass, hence at all points above the apex of the base pyramid the shrinkage at each end of the imaginary line of crystals running from the mould face to the axis should be the same. This would mean that the shrinkage pipe or cavity would be a parallel square hole reaching to the top of the ingot, which is not the case. The usual pipe is, of course, a cavity having the form of an inverted cone. Even

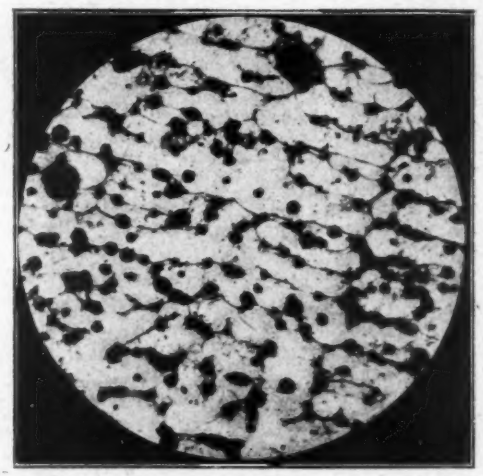


FIG. 10.

in a square ingot the cross section of the pipe is usually circular, as is clearly shown in Fig. 12, which is the photograph of a typical ingot.

By admitting that as the crystals in the above case form they eject a portion of their occluded gases into the mother liquor, it is easy to see that

a portion of these gases is gradually driven to the axis, where it ascends by way of the liquid centre. These gases, as they flow axially and ascend, leave cavities in their wake, which are more less filled with molten metal. If the metal is at all viscid, the whole of the gas does not reach the ingot top, and hence is trapped. Each stratum of metal drives its ejected gases towards the axis; hence, as these gases rise, they increase in volume, being added to at each stratum. If the increasing density of the metal towards the ingot top is ignored, the shape of the gradually growing central gas globule would be a sphere. But the density of the metal diminishes as the top is approached, and the temperature likewise increases; hence the otherwise spherical bubble becomes pear-shaped, and when it reaches the frozen crust, which it cannot always penetrate, the top of the pear is flattened. In the cases where the top of an ingot is purposely chilled by pouring water thereon, as was the practice in some works years ago, the inner cavity is circular in section, and smooth-sided, indicating clearly the pressure of the pent-up gases (Fig. 13). By calculating the difference in volume between the liquid and the solid ingots, it will be found that the volume of the pipe or cavity in otherwise sound, well-killed steel corresponds very nearly to such difference.

This leads to an important question. Is the phenomenon of shrinkage connected with the volume of occluded gases, or, rather, with that of the gases escaping during the freezing of iron and steel? There are many evidences in favour of such a conclusion. A case in point was that of a mild steel block, which was cast from a ladle of well-melted steel held in the ladle accidentally until close on the point of setting or congealing. The nozzle gave out, and allowed of scarcely any steel rising in the casting head or riser. When

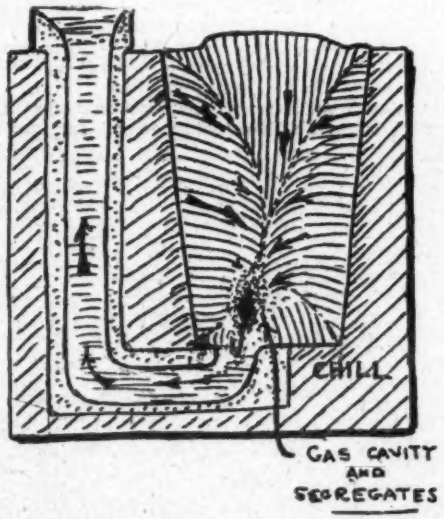


FIG. 11.

cold the block was found to have contracted less than 1-16th of an inch per foot. The metal under the rising head (which was less than ½ in., and should have been 3 ft.), when planed, revealed no pipe or cavity, and was free from blow-holes. The weight of the casting indicated soundness. Does not this point to the fact that here the gases escaped freely during the slow rising of the steel in the mould, and that the finally occluded gases remaining in the metal mass were in a fine state of entanglement between the crystals, uniformly throughout the mass? A similar casting made in the same heat from the more fluid steel piped deeply in the rising head, and contracted normally at the rate of 0.2 in. per foot.

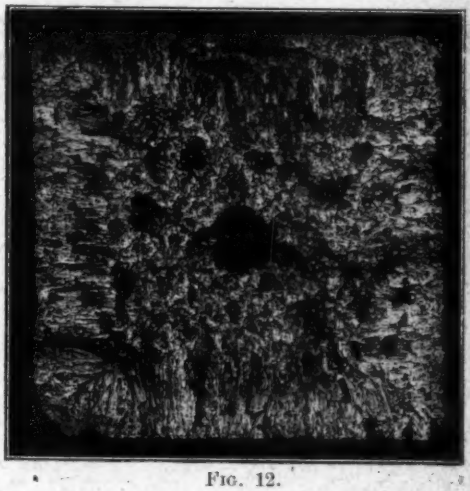


FIG. 12.

In another case a grey cast-iron cylindrical block was cast, in the centre or axis of which was fixed an iron tube twice the depth of the block. The molten iron was run into the mould surrounding the central tube or core. The iron tube was next filled with metal and the whole allowed to cool down slowly (Fig. 14). When parted through near to the upper surface of the block at Y Y, the expected ring-shaped pipe was found in the outer ring, but the inner tube was found to be perfectly filled with metal, which had not contracted. The inner ingot was again parted through just above the block at X X, and here again no contraction had occurred, though at the top of the inner tube or ingot there was slight shrinkage. Two gas cavities were found in the inner ingot, one at the top, and another almost opposite the top of the cylindrical block. The explanation would seem to be that the metals in the lower half of the inner ingot, being surrounded by a heated mass of the same temperature, could freeze so slowly, as to eject its gases axially and upwards, the bubbles being perfectly replaced by liquid metal. Hence the lower half of the central ingot did not contract. The escaping gas met the bridge of congealed metal just above the block, and was imprisoned, forming the lower cavity. The gases in the upper half of the tube escaped to the top, forming there the usual pipe.

Whenever castings are made in chilled moulds, there must be shrinkage or contraction. Here the rapid freezing tends to the formation of small primary crystals, and these, becoming quickly interlocked, imprison small gas bubbles between themselves. The cooling down of the mass later causes very considerable shrinkage of the gas bubbles, for a little consideration will show that each gas globule will occupy much less volume at 60 deg. F. than at, say, 2,000 deg. F. (less than one-fourth). Ledebur years ago called attention to the difference in shrinkage of various cast irons, and both Keep and West, in the U.S.A., and Professor Turner have

done great service to foundry science in showing how volumetric changes during the freezing and later cooling of iron varies with differing analysis. The clearest illustration of the relationship between the chemical analysis of cast iron, and the behaviour during cooling from the freezing point, with the accompanying shrinkage, has been given by Pro-

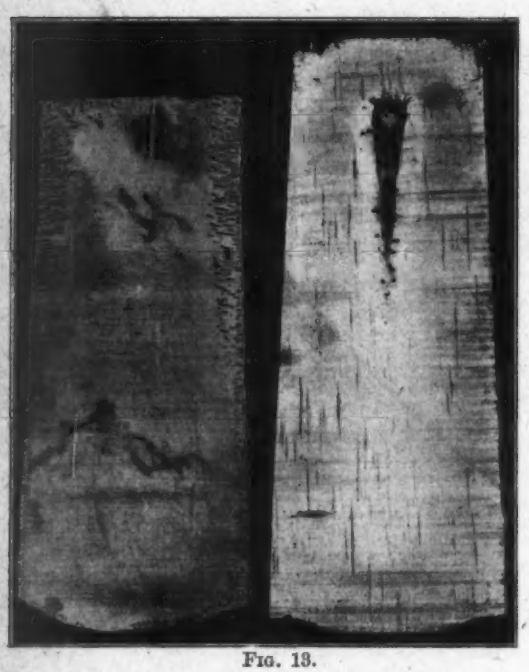


FIG. 13.

fessor Turner. He has related the freezing and the shrinkage curves, and in typical cases has shown that each grade and type of pig-iron expands on freezing, and shrinks in its own characteristic way. It was proved by Professor Turner, with Messrs. Coe and Hague, that when either silicon, manganese, or phosphorus are added to a pure carbon iron, either singly or together, there is an expansion at the moment of freezing. In white cast iron, containing about 3.5 per cent. carbon and 96.5 per cent. iron, there is no such expansion, but a rather rapid shrinkage or contraction. The addition of silicon alone up to 3 per cent. increases the expansion regularly, and similary the addition of manganese alone up to 2½ per cent. increases the primary expansion, the amount of such expansion per unit of the metalloid added being roughly the same in silicon as in manganese. Now, when the two elements—silicon and manganese—are added to the 3.5 per cent. carbon iron, it is found that the primary expansion is increased, and if a third element—phosphorus—is added, there is a further increase. In all cases there is a halt in the rate of shrinkage, and often a considerable second expansion, when the recalescence point, known as the pearlite point, or Ar1 (about 700 deg. C. in most cast irons), is reached during the cooling down from the freezing or solidification point. In the case of a grey Northampton iron containing 3.5 per cent. silicon, 0.5 per cent manganese, and 1.25 per cent phosphorus, the volume of the metal increased at the moment of freezing, and on further cooling did not really commence to shrink until 600 deg. C. or below was reached.

Now there is a very great importance to be attached to these facts. They teach us that, just after freezing commences—i.e., when the primary fir-tree form crystals begin to form next to the mould surface—a certain amount of the iron carbide decomposes, and is thrown out into the mother liquor (eutectic) as graphic flakes. This is one possible reason for the primary expansion. But when these silico-ferrite crystallites form they liberate a certain quantity of heat, and at the same time eject a considerable volume of the gases they held in solution when liquid. These gases, when thrown into the thin fluid mother liquor, would contribute to the expansion of the whole metal mass at that moment. When phosphorus is present the mother liquor is made increasingly fluid, and capable of holding more gases in solution, and of permitting their ready flow. The gases then, as may be argued from the appearance of the micro-structure, as quenched in this range of temperature, must be widely distributed as minute bubbles. At the point of recalescence (about 680 deg. to 710 deg. C.), there is another expansion (generally) connected, as Professor Turner suggests, with the liberation of more free carbon (temper graphite or annealing carbon), and probably, with a further increase in the volume of the gases as a result of the heat evolution which then takes place. Baker, in his experiments on the quantity of the gases drawn off from iron and steel heated *in vacuo*, proved that the greatest quantity is ejected at the recalescence point Ar1, thus confirming the work of earlier investigators (Troost and Hautefeuille Müller). More recently Charpy has proved that the expansion or dilatation of carbon-iron-silicon alloys is increased at the freezing point as the silicon content rises, whilst, on the contrary, the expansion at the recalescence point is diminished. (Fig. 15.) This confirms experiments made by myself on cast irons with varying silicon content some years ago, when I further found that manganese and silicon together intensified such action. Generally speaking, white iron shrinks most, the more highly silicious irons shrink least. It has been proved that silicon and aluminium tend to retain the gases in a fine state of division within the cooling mass, the decom-

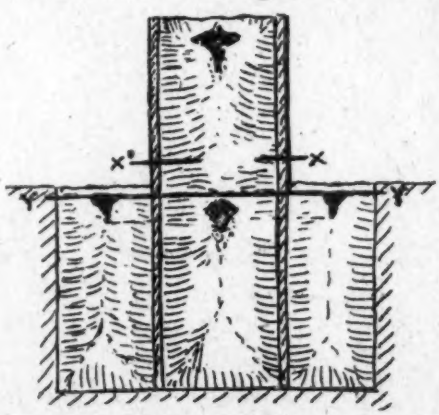


FIG. 14.

position of the carbide of iron being facilitated, graphite being liberated with considerable evolution of heat whilst the primary crystals are being formed or frozen. Hence grey silicious irons solidify slowly, and shrink least, because of the occluded gases present around and about them in the mother liquor, which is then in the ideal condition for the

free growth of the graphite flakes. It would seem that whenever the iron carbide in either the primary crystal or in the eutectic is retained, as is the case when manganese or chromium is present, the speed of freezing is increased, and the gases liberated are driven rapidly into the more fluid portion of the metal mass, where there is a tendency to shrinkage cavities. In low-silicon irons free from phosphorus high manganese (over 0.5 per cent.) generally produces such results, especially if the casting temperature is low. In the case of high manganese irons with high carbon content used in rapidly-cooled castings, the difference in the shrinkage rates between the outer freezing zones high in combined carbon, and the inner zones of grey iron, not rarely results in pulls or draws in the outer skin, especially in the neighbourhood of internal corners (where three planes meet). The presence of phosphorus is an aid to gas escape into the hot interior of a cooling casting. The increased fluidity given by reason of the fluid phosphide eutectic makes it easy to feed castings made from metal containing above 0.4 per cent phosphorus.

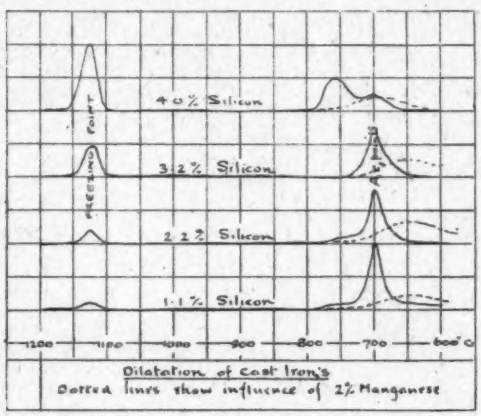


FIG. 15.

The feeding process is really the means of supplying liquid metal to take the place of the gases which are being liberated, as the primary crystals are growing at the expense of the gradually diminishing mother liquor. When, by reason of low carbon content, the constituency of a cast iron is steely in its nature, then there is great danger of internal sponginess, and, as the gases occluded are considerable in volume, and the difficulty in feeding increased, through the rapid character of the primary crystal freezing, there may be brought about serious cooling strains.

The addition of mild-steel scrap to cast iron in cupola mixtures produces this class of metal; the curling and distortion during the cooling of plates or the like made from such indicates the trouble hinted at above.

Similar difficulties occurred in the early days of steel-casting manufacture, when the relative values of silicon and manganese were little understood. Innumerable contraction troubles resulted from the use of high-manganese and low-silicon steel—i.e., 0.9 Mn. 0.1 Si.—whereas the employment of higher silicon—0.3 to 0.4—with lower manganese—0.4 to 0.5—has mitigated the evil.

The question of hot casting is, of course, allied to the problem of shrinkage and of gas exit. Generally, it may be stated, when the metal is hot cast—i.e., its molten temperature is higher than that necessary to melt it simply—the gases which are liberated during freezing are driven into the hot interior, where, as they escape to the risers, their place is taken by liquid metal. There is a better distribution of the gases which remain in the cold metal, and less risk of blow-holes and gas cavities common with cold-cast metals.

The late Mr. George Hailstone carried out researches of a useful character on what he called liquid contraction—i.e., the local contraction which takes place in the heavy part of a casting when the outside skin of that casting has solidified. He connected gas inclusion, and the temperature of casting with the problem. It is clear that unless the temperature of casting iron exceeds the melting point of the primary crystals, and these rarely contain more than 1.8 per cent. carbon (namely, about 1400 C.), the certainty is that these primary crystals, in freezing rapidly, drive considerable quantities of gas into the central slow cooling mass.

With hot-cast metal these gases are more uniformly distributed throughout the casting, a greater part escaping through the risers or feeding heads. The importance of hot casting will be at once seen when dealing with pure irons of hematite and cold-blast character, low in total carbon, phosphorus, and silicon. Such iron cools and shrinks rapidly, because its primary crystals freeze at a high temperature, and the mother liquor being more purely eutectic freezes rapidly. Being thus difficult to feed, owing to the passage through the "pasty" stage (which can be so clearly observed in the puddling process), the gases pent up in the mass centres of the casting become frozen in, and remain as shrink holes, or gas cavities.

Cast irons which are high in silicon and phosphorus do not suffer from the slow freezing of the eutectic. This mother-liquor, which is a kind of compound eutectic, has a longer freezing range than the simple 4.3 carbon eutectic. Moreover, during the freezing of the primary crystals the carbide of iron therein decomposes, graphite being liberated. The heat evolved keeps the mother liquor in a fluid condition, and there is no "pasty" stage. Anyone who has observed the puddling of such irons will understand the difference between the behaviour of a white refined iron of the old refinery plate type and that of a Lincolnshire grey pig-iron. The latter is liquid for a much longer period than the former, and is most difficult to puddle, because the primary crystals remain for so long in an almost fluid condition. Manganese retains the carbide in the eutectic and assists the rapid freezing thereof. It also stiffens the primary crystals. It has a powerful effect in conjunction with silicon in suppressing the heat evolution at the pearlite point (about 680 deg. C.), as the cooling curves show. I have generally noticed that such suppression of the pearlite point, if accompanied by a lowering of the freezing point, indicates a tendency to rapid freezing of the primary crystals which are found to retain the austenitic condition even when slowly cooled.

With reference to the character of the gases occluded in iron and steel, a great deal of research work has been done, notably by Dr. Baker. Gases exhausted *in vacuo* from cast iron and steel at temperatures in excess of 900 deg. C. have given the following analyses :—

	Per cent. by volume.
Carbon monoxide	45 to 50
Hydrogen...	45 to 55
Carbon dioxide	0 to 5
Methane	0 to 3
Nitrogen	0 to 4

In cast iron the gas analysis is more variable than in the case of steel, nitrogen being present in much higher proportions, though in some experiments the gas analysis has been found to be much the same as in the case of steel. It would appear that the absorption of nitrogen in the tuyere region, and possibly during casting, has much to do with this fact. The later conversion and refining in the steel furnace may acount for its absence in the finished steel. It has already been hinted at that the office of CO in the blast-furnace reactions, and the presence of moisture in the blast and raw materials, most probably account for the presence of carbon monoxide and hydrogen in the occluded gases found always in iron and steel. These gases, moisture and CO, are found together in the high temperature of the tuyere zone of the blast furnace. The water vapour is dissociated in the presence of incandescent carbon, and the gases H_2, and CO are the result of a reaction thus :— $H_2O+C=H_2+CO$.

The relative weights of the H and the CO are as 6.6 : 93.4, which corresponds to the volumetric proportion found in the gases withdrawn from white-hot metal. It is highly probable that such a reaction as above cited takes place with extreme rapidity and vigour, and it is not difficult to imagine the gases thus formed entering the liquid or semi-liquid metal as it enters the hearth. Such a theory, of course, opens the way to the problems concerning the retention of the individuality or entity of the iron crystals during their entire existence from the pig-iron to the later steel state; from their birth in the reducing zone to the blast furnace, their after-life in the molten state in the hearth, in the frozen state as pig-iron, in the re-melted condition, and in the refining stages of the steel furnace; followed by their final freezing as steel, and so on through the various after-chapters when reheated, rolled, or forged, heat treated and cooled.

There is much to support the idea above expressed, perhaps for the first time, though Dr. Howe has done much to foster ideas in this direction. It is a remarkable coincidence, however near to the actual truth my surmise may be, that the analogy between the analysis of the gases drawn off from white-hot metal, and the quantitative analysis of the gaseous mixture produced by the water vapour and carbon reaction, is so close.

The foregoing matter all illustrates the importance of taking into consideration the influence of gases in the foundry problem. Unless efficient means are taken to secure the easy escape of gases liberated during the soldification of cast iron and steel, the occluded gases which remain entrapped expand again during the recalescence, and may do further mischief, especially in the region of the spongy places, which, removed from possibility of proper feeding, may be the starting-places of cracks and fissures, the spreading of which may lead to serious accidents later.

It is scarcely necessary to add that the major portion of foundry troubles are associated with the question at issue. The gases which are set free at the mould surfaces, due to the driving off of moisture in the sand washes or moulding composition or of the volatile matter in the same, belong to a different category, and should, of course, be dealt with separately. The practical value of our investigation is seen when the compositions of pig-irons is compared with their shrinkage per unit volume during the cooling down from the freezing point to the temperature of the atmosphere. The following table may be found useful in relation to what has already been said :—

Combined carbon.	Graphite.	Si.	Mn.	P.	Volumetric Contraction	Class of iron.
%	%	%	%	%		
0.45	3.33	2.8	1.2	0.8	1/17	Coarse grey
0.40	3.01	1.5	1.3	0.4	1/20	Light grey
0.93	2.35	1.0	0.4	0.7	1/27	Mottled
1.20	2.15	0.9	0.2	0.4	1/31	Mottled
1.50	2.10	1.0	3.2	0.5	1/33	White iron
5.00	0.20	0.7	11.2	0.1	1/40	Spiegel

Finally, the practical use of a thorough knowledge of the gas problem in foundry work is obviously in properly choosing the metals which are likely to give the soundest and strongest castings with the minimum of works difficulties.

Also, in order to make the best use of such metals the design of the articles to be moulded should be such that the feeding of the portions which are the most remote from the possible feeding heads can be effectively carried out so that the gases can readily escape. There are innumerable cases of machine details so designed that hidden gas cavities are inevitable. The junction of two or more planes, the disposition of massive and light adjacent sections, and the discriminate placing of stiffening ribs and cores, to name the most important of a number of points in casting design, need the close and studied attention of the draughtsman and designer.

So important is this question becoming in these days of light high-speed heavily-stressed machinery that it is fast becoming imperative that the designing engineer should be thoroughly saturated with the principles of the metallurgy of iron and steel, and of the non-ferrous metals.

It goes almost without saying that the foundryman should seek without delay the close acquaintance of those avenues of metallurgical knowledge which are now open to him. The broad outlines of scientific research have already been drawn by those who have, through much difficulty and a succession of seeming failures, arrived at the explanation of many hitherto mysterious happenings. It is for the men in the works to fill in the outlines, and to discover many areas which are not open to laboratory researches alone.

[The discussion on the Paper will appear in our next issue.—Ed. "F. T. J."]

Use of Copper for Casting.

The Ministry of Munitions announce that from January 1 no copper will be supplied for the purpose of casting brass or other copper alloy, and no brass or other copper alloy may be cast except for the purposes of Class "A" or Class "B" orders, under the Ministry of Munitions Circular L. 33.

Non-corrosive Aluminium Alloys.—Certain aluminium alloys which were claimed to have considerable resistance to corrosion were the subject of a patent granted to G. Jacquier. The composition of one was :—Aluminium, 92 per cent. ; copper, 5 per cent. ; bismuth, 2 per cent. ; silicon, 1 per cent. The silicon was introduced as silicon-copper, and the aluminium introduced after the other metals had been melted. Another alloy given had the composition :—Aluminium, 91 per cent. ; copper, 5 per cent. ; bismuth, 2 per cent. ; magnesium, 2 per cent. Again the aluminium was added last.

Some Copper-Aluminium-Iron Alloys.*

By W. M. Corse and G. F. Comstock.

One of the properties which aluminium bronze possesses to a higher degree than other important bronzes is that of dissolving iron when melted and retaining this element in the solid alloy. The standard aluminium bronze made extensively for small and average castings by the Titanium Alloy Manufacturing Company contains 10 per cent. aluminium and 1 per cent. iron, and experiments have been made with larger amounts of iron in bronzes containing 7 per cent. to 10 per cent. aluminium inclusive. The following gives some of the preliminary results obtained in the examination of these alloys.

No alloys with less than 7 per cent. aluminium were used in this work, because they are too soft and weak to have any large degree of usefulness for castings in which strength is necessary. Ten per cent. aluminium was the higher limit adopted, because with more than this the alloys have very little ductility, and for this reason are not used

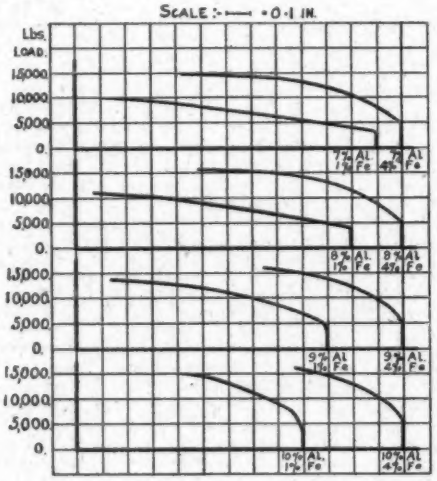


FIG. 1.—TYPICAL LOAD-DEFORMATION CURVES OF SOME COPPER-ALUMINIUM-IRON ALLOYS.

except in rare instances where great hardness is required and brittleness is not ruinous. Alloys with over 8 per cent. iron were not investigated, because of their unpromising character, judging from the other alloys tested, and also because of the difficulty of making such alloys and obtaining uniform castings. The tests consisted primarily of tensile tests on cast-to-size bars, and the Brinell hardness was determined on many of the stubs after pulling. A sufficient number of these alloys was examined with the microscope to indicate the general microstructures of all of them.

The tensile test bars were cast in sand about 8½ ins. long and ½ in. in diameter between shoulders which were 2 ins. apart. At least four bars of each alloy were tested without machining, the surfaces merely being smoothed where necessary with a fine file, so that the true average diameters could be measured with a fair degree of accuracy. Some of the bars from each heat were tested with the autographic mechanism in use on the testing machine, so that load-deformation curves were obtained from which the proportional limit could be read. From the other bars the yield point was found by noting the load at which a deformation of 0.01 in. was produced on the 2-in. gauge length, as measured with fine-pointed dividers. Results from test bars showing flaws or other unsoundness in their fractures were discarded unless the defect had no harmful influence on the physical properties; the figures tabulated below were then obtained by averaging the results from the sound bars.

The hardness tests were made on cross-sections of the ends of the bars cut after they had been broken in tension. A standard Swedish Brinell machine was used for this determination, with a 10-millimetre ball, and pressure of 500 kilograms applied in each case for 30 secs. The hardness figure was obtained from the usual table after measuring the diameter of the depression with a microscope containing a tenth-millimetre scale mounted in its field of view.

The results of the tests are here tabulated, and Fig. 1 shows accurate copies of some of the typical load-deformation curves.

Table I.

Alloy.		Lbs. per sq. in.			Elongation % in 2 in.	Reduction of area %	Hardness No.
% Al.	% Fe.	Proportional limit.	Yield Point	Tensile strength.			
7	1	14,300	15,700	53,200	56.0	54.2	70
	2	17,400	18,900	63,000	39.0	35.6	70
	3	21,300	23,300	74,500	38.0	32.2	80
	4	22,100	23,600	76,400	38.5	35.7	89
8	1	16,400	19,500	57,100	45.0	43.4	70
	2	18,200	20,600	63,800	39.0	39.2	80
	3	24,200	26,000	81,100	36.5	32.9	109
	4	24,800	26,300	82,100	35.0	32.0	109
9	1	18,500	23,300	69,500	43.0	35.7	77
	2	22,400	25,800	78,300	30.5	27.4	109
	3	25,600	28,300	81,700	26.0	26.9	109
	4	26,400	28,500	83,000	23.0	23.8	109
10	1	19,800	24,000	77,000	24.5	25.2	94
	2	22,800	26,700	82,600	21.0	19.2	109
	3	26,100	28,800	86,400	20.0	20.5	109
	4	27,400	30,000	88,600	17,0	18.5	119

From this table it is seen that for the same aluminium content there is always an increase of proportional limit, yield point, and tensile strength with increasing iron content, and in general a rather less substantial decrease in elongation and reduction of area. In the same way, with constant iron content, the proportional limit, yield point, and tensile strength increase with increasing aluminium, while the elongation and reduction of area decrease. Furthermore, for a given strength, better ductility can be obtained with a lower aluminium and high iron alloy than with higher aluminium and low iron. Thus the 8 per cent. aluminium with 4 per cent. iron is better in every respect than the 10 per cent. aluminium with 1 per cent. iron, and even the 7 per cent. aluminium with 4 per cent. iron is practically equal to the latter in strength, but far superior in ductility. The excellence of the alloys with 4 per cent. iron made it seem advisable to try still higher percentages, and this was done with the 7 per cent.

* Abstract from paper read at Annual Meeting of American Institute of Metals, 1916

and 10 per cent. aluminium series. The difficulty in obtaining sound and homogeneous bars was not so successfully overcome with these higher percentages of iron, however, and the results were rather irregular and disappointing. They are tabulated below, together with the results from the previous table on the 7 per cent. and 10 per cent. aluminium series, and these figures are all shown plotted in

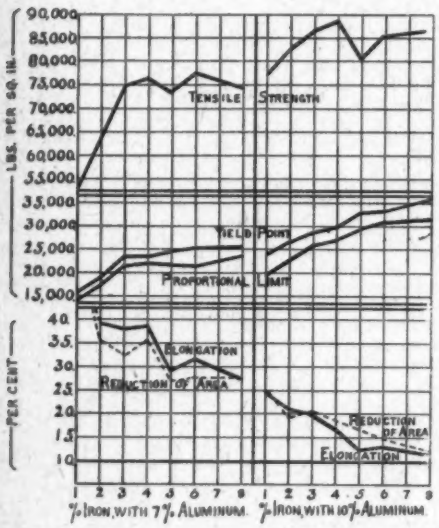


FIG. 2.—PHYSICAL PROPERTIES OF 7 PER CENT. AND 10 PER CENT. ALUMINIUM BRONZES WITH 1 PER CENT. TO 8 PER CENT. OF IRON.

Fig. 2 to indicate the manner in which the various physical properties change with the iron content in the two series.

Table II.

Alloy.		Lbs. per sq. in.			Elongation % in 2 in.	Reduction of area, %
% Al.	% Fe.	Proportional limit.	Yield point.	Tensile strength		
7	1	14,300	15,700	53,200	56.0	54.2
	2	17,400	18,900	63,000	39.0	35.6
	3	21,300	23,300	74,500	38.0	32.2
	4	22,100	23,600	76,400	38.5	35.7
	5	21,600	24,700	73,600	29.0	26.9
	6	21,500	25,300	77,500	31.5	27.6
	8	23,600	25,600	74,600	27.5	27.6
[10	1	19,800	24,000	77,000	24.5	25.2
	2	22,800	26,700	82,600	21.0	19.2
	3	26,100	28,800	86,400	20.0	20.5
	4	27,400	30,000	88,600	17.0	18.5
	5	29,500	33,000	80,600	12.5	16.9
	6	31,000	33,500	85,500	13.0	14.7
	8	31,900	35,900	86,550	11.5	12.4

These tests indicate that although the proportional limits and yield points increase fairly regularly with the iron contents, the ultimate strengths do not change much after 4 per cent. iron, and the ductilities drop decidedly. The best alloys, considering both strength and ductility, appear to be those containing between 3 per cent. and 4 per cent. iron; with more iron than this there is considerable difficulty in obtaining sound and homogeneous castings, and there is only a slight gain in strength with too much decrease in ductility.

It was noticed in pulling the bars with 7 per cent. and 8 per cent. aluminium, that those containing little iron roughened very markedly on their surfaces, so that the outlines of the crystal grains stood out very prominently, some being raised up in relief above the others. With 3 per cent. or more iron, however, the bars were round and smooth after testing. In the higher aluminium series, the sound bars with 3 per cent. or more iron had a more uniform, finer-grained, and more fibrous fracture than those with less iron. The comparative microstructures threw considerable light on these facts, which were certainly caused entirely by differences in structure.

OXYGEN GAS IN BLAST-FURNACE OPERATIONS.—Oxygen gas under pressure in cylinders is an efficient aid in keeping the blast furnace to time with its casts and in minimising the extremely hard work attending the recovery of a furnace that for any reason has run off cold. The apparatus in use on the blast furnace at the Broken Hill Proprietary Company's steel works in Newcastle, New South Wales, Australia, consists of two gauges with a reducing valve between them, such as is used with the oxy-acetylene blowpipe, a heavy ¼-in. rubber tubing about 30 ft. long with a ¼-in. bend in one end, and a number of ¼-in. pipes about 18 ft. to 20 ft. long. A sleeve is kept on the end of the bend not in the tubing, which allows of a quick connection with the pipe. Mr. David Baker, in "The Iron Age," describes its use in a hard tap-hole as follows:—"We have drilled in, say, with a hand drill until it seems as if we have struck a granite wall. Probably by this time we have struck a thick iron skull, though not necessarily so. The hole is very likely to show a dull red. Then a container of oxygen is brought up, and a ¼-in. pipe is connected to the bend at the other end of the rubber tube. If the hole is a bright red it will probably be hot enough to cause the oxygen to set the end of the ¼-in. pipe burning and this will quickly burn the hole out. If the hole is too cold for this, a small coke fire may be started in the cinder run and the end of the pipe may be thrust into this and started burning in this way. Once started the pipe is quickly thrust into the hole and held up against the skull before it stops burning. It may take a number of pipes before the hole is burned through, for, of course, the pipe quickly melts off, but it practically never fails to bring the iron. It must be kept in mind that the ¼-in. pipe must be kept burning to have any effect. After one pipe is burned off the remaining short piece is unscrewed from the bend and another long piece is screwed on. The pipe will immediately light up from the molten material lying in the hole. This is kept up, replacing the tubes as quickly as they are burned off, until the hole is burned through; and it is a very bad case that will not yield to this treatment in 15 to 20 minutes. The apparatus works best, of course, where the hole is plugged with iron or at least where there is a big percentage of iron in the hole. However, I have at times burned through a foot or 15 in. of slag and clay, with very little if any iron in it, and have opened a hole in 20 minutes to half an hour that by ordinary methods would have taken three to four hours of hard work. The tools that I have regularly used to open the hole consisted of an electric twist drill with which to open the hole to the skull and a hand drill operated by the whole furnace crew to punch through the skull, keeping the oxygen apparatus as the final word. A second use to which the oxygen was put, and very successfully, was that of opening the cinder notch. A third and no less important use to which oxygen may be put is in burning out tuyeres which have become plugged with iron. The secret of this apparatus is that if oxygen is used in an open face of a size to allow of a great deal of radiation the result is failure, but if it is used in a pocket where the heat is generated much faster than it can be radiated or carried away, then an intense melting action takes place, the burning of the iron furnishing the heat."

Production of Aluminium Castings.*

By J. Gaunt.

Aluminium itself is a soft, white metal with a low specific gravity (2.56), a low melting point (657 deg. C.), and a low tensile strength.

In its purest state it is of little use for industrial purposes, and must be alloyed with other metals in order to increase its tensile strength, and render it fit for service. In attempting to alloy aluminium, difficulties arise in that aluminium does not readily unite with other metals to form homogeneous mixtures, but forms definite compounds with them, which separate out during cooling, giving a matrix of pure aluminium in which are embedded the compounds so formed.

Alloys of aluminium and zinc, however, seem to cool out in the state of solid solutions. With up to 40 per cent. zinc this condition prevails. The zinc alloys have therefore found a wide application in industry, and are the most commonly used of all the aluminium alloys. With zinc up to 15 per cent. the metal may be classed as soft, but beyond that it becomes more brittle as the percentage increases. The tensile strength of the alloy also increases with the percentage of zinc, increasing from 10,500 lbs. for pure aluminium, to 30,000—35,000 lbs. with 32 per cent. of zinc.

In America copper is favoured as a hardener for aluminium, its action being similar to that of zinc, though beyond 12 per cent. the castings become very hard. One of the chief advantages of the aluminium-copper alloys is the ease with which they may be cast, and the comparatively small amount of trouble which is experienced through "drawing." The addition of 1 to 2 per cent. of copper to the alloys with zinc is of great assistance in the casting of sound metal. As with zinc, the tensile strength increases with the copper, reaching 22,000 lbs. at 12 per cent.

Other and more complex mixtures are used in special circumstances, such as for pistons for internal-combustion engines, but probably 90 per cent. of castings are made from aluminium-copper or aluminium-zinc alloys.

In regard to the alloying of the above mixtures, zinc is easily introduced to any extent by direct addition to the molten aluminium, but with copper it is first necessary to make up a hardener in the form of a 50-per cent. aluminium and 50 per cent. copper mixture. The copper is first melted and the temperature allowed to fall, after which the aluminium is added, and well stirred in. This is cast into ingots which are very brittle and easily broken up for weighing out the requisite quantity for any mixture.

As with all other alloys, after the first few melts from new alloy, there comes to be a quantity of scrap in the form of runners which must be used up, and the question of preserving the balance of the constituents arises.

In brasses this means that a loss of zinc occurs which has to be made good in the remelting. In aluminium alloys the reverse is the case, and it is the aluminium content which is lost through oxidation, and the zinc content is increased by the ratio to this loss. Consequently, instead of the usual addition of zinc, it is necessary to compensate by the addition of more aluminium, and I think a fairly average addition is 2 per cent. of the aluminium content. This is a point on which many founders go astray at first, and, considering the difficulty of obtaining a zinc which is 99 per cent. pure it is easy to see how trouble may arise from not taking the necessary precautions.

For those who do not care to make up their own alloys, it is always possible to obtain them in ingot form from the makers of aluminium, at a cost of about £5 per ton above the market price of the metal.

Melting.

In melting aluminium great care is necessary to avoid overheating, and too much emphasis cannot be laid upon this point, especially where the melters have been accustomed to melting brass or gun-metal. More trouble may arise from a careless overheating than from any other cause.

To illustrate the point, I have two specimens of aluminium of identical composition, one of which is properly melted, and the other overheated. The overheated metal is very porous, and shows under the glass a spongy appearance. It is taken from the side of a casting, and should therefore be free from dirt, and it is typical of the rest of the casting.

The molten aluminium should not reach above a dull red heat, and if by any chance it does, it should be immediately cooled down by the addition of runners or new metal. The use of a pyrometer is to be strongly recommended, and as a sheath is not necessary for a thermo-couple at such low temperatures, a rapid and accurate check can easily be kept upon the metal.

The time taken for each reading is not more than 30 seconds, so there should not be much time wasted in this operation. In all cases where temperatures are mentioned in the following remarks, these have been determined by a thermo-couple pyrometer made by the Foster Instrument Company, Letchworth, suitable for temperatures up to 2,500 deg. F. The melting point of aluminium is about 1,215 deg. Fahrenheit, and, allowing for variations in thickness, it should not be necessary to exceed 1,300 deg. Fahrenheit at any time. I will give my reasons for this later.

During melting the metal should as far as possible be kept from undue contact with the fuel, even at the expense of a high melting cost, wherever the work is of an important nature. At present there seems to be no suitable covering for the metal during melting, as, owing to the lightness of the metal, such coverings as charcoal are apt to become entangled in the metal, and cause dirty castings. A slight oxidation is therefore unavoidable, and to remove the oxide, which is of a spongy nature and mixes in the metal to form porous castings, zinc chloride should be used as a flux. Small pieces are thrown on the surface and stirred in, until the surface of the metal clears. The dry powder which is then left floating on the top should be skimmed off, and the metal will be found to be clean and fluid.

There is some controversy as to whether iron or plumbago makes the most convenient crucible for

* Read before the London Branch of the British Foundrymen's Association, December 15, 1916, Mr. A. R. Bartlett in the chair.

melting aluminium. This usually reverts back to the point: "Which is the most economical?" Iron crucibles certainly are the cheapest, but for a high-quality metal there is nothing to beat the plumbago crucible, which, if properly handled, will give a long life. With an expensive metal like aluminium, it is sometimes probable that the cheapest form of melting is in the end the dearest, as the spoiling of one batch is a matter for serious consideration. As to cost of melting, I had prepared some comparative figures, but at present will only remark that if good sound metal is obtained, then whatever the cost within reasonable limits, it is economical.

Casting Temperature.

Casting temperature plays an important part in the making of sound castings. This should be taken in conjunction with the melting temperature, of course, but even overheated metal, if it is cooled down before pouring, will give better results than if poured at a high temperature. The effect of casting temperature on tensile strength is very great, varying 2,000 to 5,000 lbs. between, say, 1,225 deg. F. and 1,600 deg. F. That is, the tensile of an alloy poured at 1,225 deg. F. will be 2,000 to 5,000 lbs. greater than that of the same alloy poured at 1,600 deg. F.

In connection with pouring temperatures, we were recently pouring a certain casting at as low a temperature as possible, and were experiencing some trouble due to some small bosses "drawing." As these were set across the joint of the mould, it was difficult to introduce a chill to prevent this. On casting at a higher temperature, it was found that this "drawing" was avoided. This led to experiments being made with a view to finding the effect of casting temperature on contraction. A Keep's testing apparatus was used, and a half-inch square bar cast between 12 in. yokes, and the shrinkage measured after cooling. The following were the results:—At 1,260-70-80-90 deg. F., the shrinkage varied between 0.182 and 0.186 in. Above 1,300 deg. F. the shrinkage was constant at 0.180 in, the bars being cast at 10 deg. intervals up to 1,380 deg. F. The experiments will be extended in the near future by a microscopic examination of the bars, with a view to finding out whether there is any structural difference in the metal when cast above 1,300 deg. F.

On the results as above set out it will seem that the metal sets in a denser form below 1,300 deg. F. than it does above. Certainly metal cast at above 1,300 deg. F. displays greater tendency to porosity under hydraulic pressure than that cast below 1,300 deg. F.

The effect of casting temperature on soundness is illustrated by experiments conducted on a water jacketed section of an induction pipe. By soundness I do not mean freedom from outward and visible defects, but soundness under hydraulic pressure. Visible defects can often be overcome by chills and risers, but often an apparently sound casting will show defects when subjected to pressure. The casting submitted is an example of this, as it is porous under pressure, and is an ideal subject for the study of casting temperature and its effect on soundness.

The castings in the table given were numbered from 1 to 6, and poured in the order given. The alloy was copper 8, aluminium 92. It has since been altered to copper 8, aluminium 90, tin 2, the tin seeming to make the obtaining of sound castings easier, possibly by liquating out into any porous parts:—

Cast at	1,350°.	1,300°.	1,275°.	1,270°.
1	B	B	Slightly porous	G
2	B	B	G	G
3	B	Slightly porous	G	G
4	B	"	G	G
5	B	Bad casting	G	G
6	G	G	G	G

I am sorry that these experiments could not be further extended, but pressure of war work prevents continued research.

In regard to fluidity, I do not think there is any great variation if the metal is above its melting point, and the sand is not too hard or wet. These are the reasons for saying that 1,300 deg. F. should never be exceeded.

Moulding.

In the earlier days of aluminium casting the moulding practice followed along the lines of iron founding, except that chills were much more freely used. The recruits to the ranks of aluminium moulders came from the iron foundry, and eventually developed the handling of moulds and the metal to the present state. It may be interesting, therefore, to show the points of dissimilarity between iron and aluminium founding, and it will at the same time serve to emphasise the fundamental principles underlying modern practice.

First, as to the lightness of the metal; with a heavy metal like iron, the steam and gases generated during casting have to overcome the resistance of the molten metal before a "blow" can take place, and as these gases will naturally follow the line of least resistance, this will be in most cases through the sand. Therefore, taking two moulds of entirely similar consistency and casting, one with iron and the other with aluminium, the resistance of the metal to the passing of gases through it will vary in the ratio of the specific gravities of the two metals—that is, roughly, 3 to 1. So whilst the iron casting might be perfectly sound, the aluminium casting might be "blown," owing to the smaller resistance of the molten aluminium.

From this one might incline towards certain remedies, such as using a much drier sand, venting more freely, or using a much more open or self-venting sand. A drier sand is good, but with dry sand—that is, a dry green sand—the cohesive properties of the sand are diminished, and we might expect trouble with sharp edges and with the cope sides.

Dry-sand moulds would overcome the difficulty, but only by adding a further one due to the high shrinkage of the alloy and its pasty condition at high temperatures. The dry-sand moulds would, unless speedily eased after casting, cause the casting to crack, by offering a resistance to the contraction at a time when the metal was in its weakest phase.

The more open sand is also to be avoided, owing to the rough matte surface it would give to the casting. Most aluminium castings are expected to show a fine smooth skin, as rough-skinned castings look very unsightly.

Venting is a way out of the difficulty, but not a very good one, as the use of the vent wire often disfigures a pattern more than the usual fair wear and tear. Especially is this so in the case of machine moulding, where the vent wire would often need to be placed into unskilful hands, and where sleeking with tools to remove the marks of the wire might result in worse-looking castings than if the wire marks had been left in the mould.

The lightness of the metal itself presents its own solution to the difficulty. The specific gravity

being low, and the head pressure almost negligible, the mould does not need to be rammed so hard as in iron in order to retain the metal to the shape of the mould without swells or similar troubles. That being so, and the sand consequently rammed lighter, the mould provides its own porosity through the reduction in density, and the temper or the dampness of the sand used can be much the same as that for iron moulds, and closer in the grain, to give a smoother surface. No mould for aluminium need be expected to blow if properly rammed.

Shrinkage.

With iron castings the shrinkage is much less than in aluminium, and in the majority of castings nothing need be feared in regard to shearing, even in the case of castings in which hard dry-sand cores are used.

Iron on solidfying soon acquires considerable strength, but at this stage aluminium is in a very weak and pasty state, and the slightest resistance to contraction or the slightest jar breaks the casting. Consequently, the use of dry-sand internal cores in an aluminium mould makes it necessary to strip the mould quickly in order to remove the core and give the metal a chance to contract. Care must be taken not to fracture the casting by rough handling during this operation. Shrinkage in the heavier portions of the mould has to be overcome. Here again the contrast with iron is great. In aluminium the shrinkage calls for drastic treatment, and heavy chills or large risers are necessary to overcome it. Heavy risers, where possible, are the best treatment for heavy sections, and chills should be avoided as far as possible and reserved for use on such parts as are inaccessible to the placing of feeders. Excessive use of chills introduces further risks, as the metal (again aided by its lightness) is inclined to blow off them. For this reason many people like to warm the chills as they lay in the mould, but this seems an unnecessary procedure, as, unless the mould is to be poured immediately, they return to their previous state in the interval before pouring.

Runners.

The runners for aluminium at the point where the metal enters the mould can be very similar in size to those for iron, the U or gouge-shaped section being the most serviceable. An increase in the number of in-gates is an advantage, and these should be arranged so as to be spaced over the whole of the casting.

Running into the side of the casting is preferable to running on the top, but where this must be done circular runners give much better results than wedge-shape, and in placing them care should be taken to put them in the heaviest parts, where the metal can flow away easily. If the casting is thin, and it is poured from the top, the metal cannot run away quickly, and it skins over; when the mould becomes full this skin flows before the metal and prevents a proper junction, or causes cracks to develop afterwards if the casting is subjected to vibration.

In running from the side, the down gates and the grips leading to the runners must be of larger section than is usual in iron, and must follow more closely on non-ferrous lines. To have them even larger than for gunmetal or brass is an advantage, as aluminium must be poured as quickly as possible, and should be led up to the point where it enters the mould with as little resistance as possible. In large work one is sometimes tempted to place two down runners side by side, connected by a large pouring basin on the top of the mould. The metal is poured into this basin, and passes down the runners, with no other force than gravity to assist it.

With a heavy metal like iron this force is great, and such runners are successful; but with aluminium this force is reduced to one-third, and may not be sufficient to cause the metal to completely fill the mould. It is far better to have only one runner, and pitch the metal straight down it, thus utilising to the full the force behind the falling metal.

To sum up, green-sand moulds, lightly but evenly rammed, chills where necessary, large risers, and quick pouring directly down the runner are essentials to good practice.

Cores.

The disadvantage of dry-sand cores has already been mentioned. Wherever possible green-sand cores should be used, and to obtain suitable results this often means constructing the core boxes in a special manner so that the core can be handled straight from the box into the mould.

Cores that can be readily handled in the green state need no special design of core box, but where the cores reach such a size that they are difficult to handle and turn over, then it becomes necessary. The usual design of core box is one of box form, in which the sand is rammed up in the box, together with grids and irons so placed as to support the weight of the core when in a position for lowering into the mould, the open side of the box being as a rule that which fits into the print. To remove the core after ramming, the whole lot is turned over on to a flat plate, with the print side resting upon the plate, as this is usually the best face on which to rest the core during drying operations. When in this position the core is freed from the box by lifting the box away from the core. The position of the core as it now stands may not be that in which it is to be laid in the mould. If the core is to be dried this does not much matter, as a dry core is readily turned into a reverse position; but if it has to be turned over green it may be rather a tricky operation.

To overcome this boxes can be built with a loose bottom plate, on to which is dowelled a frame. The bottom plate forms the bottom of the core, and the frame is simply to hold the sides in position. These sides, which form the sides of the core, and carry any bosses or projections, fit into the frame, and are tapered to suit the taper in the frame.

The advantages of this box are: The frame, which is easily renewable, takes all the rough wear. No cramps, dogs, or sash screws are required, and what would be loose pieces in an ordinary box are firmly fixed to the sides.

In working, the sides are laid in position on the bottom board and the frame dropped over them, thus at once locating them accurately. In ramming the core the sides are wedged outwards against the frame, and, as this is a constant position, it is possible to get very accurate work from the box, which, in casting thin work, is a great advantage. When the core is rammed up the box is rapped and the frame removed. Next the sides are drawn away in the direction of any bosses or other extending parts which may be attached to them, and the core is left standing on the bottom board in the position it occupies in the mould. From here its transference to the mould is simply a question of lifting facilities.

With a little study it is surprising how far this

principle may be applied, and to what extent it can be used for overcoming that bugbear of foundrymen—i.e., "loose pieces."

As regards core sand, this should be similar to the sand used for the moulds in all cases where the core can be handled green. In cases where it is necessary to use dry-sand cores, care must be taken that these are of such a composition as not to interfere with contraction. For instance, an oil-sand core suitable for iron would not run from an aluminium casting. For such a core a minimum amount of bond should be used, so that the heat of the metal is sufficient to burn it out.

Suggested mixtures are :—Corebind, 2½ per cent.; seasand, 97½ per cent. by bulk. Resin, 1; red sand, 2; seasand, 10. Flour, 1; seasand, 12; tempered with molasses.

For larger cores black sand from the floor bonded with small amounts of flour, resin, core gum, or similar bonds, should be used. Only sufficient bond should be used to enable the core to be handled freely, without being too hard in the casting. Cores of new sand are usually too hard in the casting and are difficult to remove.

Ramming.

Returning to the question of ramming the moulds; as I have already indicated, the moulds need not be rammed so hard as for the heavier metals, but they must be rammed evenly. The rammer must be kept well away from the pattern, and to make sure of this the sand should be well packed round the pattern before using the rammer.

By far the best way of ramming is by means of the jolt-ram machine. There is now a large and varied selection of these machines on the market, and any size casting is catered for, from ounces to tons. The action of these machines in packing the sand into the mould is favourable to the production of aluminium castings. The sand, as it is filled into the mould, is in an aerated condition, and as the sand gradually sinks under the influence of the jolt, the air forces its way out through the sand, thus automatically providing passages for the escape of the gases generated during casting. Again, by timing the number of jolts given to the mould, almost any degree of hardness may be obtained, with the certainty of the mould being rammed evenly. The question of size need not be taken into consideration, as small moulds can be quite as successfully dealt with as large moulds, the size of the machine being the only matter to decide.

Objection may be made that only large repetition orders could be handled in this manner, but, given sets of universal moulding boxes, it is surprising how small a quantity can be handled economically by means of the block system.

There are two types of machine now made, each of which gives efficient service—the shockless and the solid-anvil type. The advantage of the shockless type lies principally in the fact that no elaborate foundation is necessary, the force of the impact being ingeniously absorbed in the machine itself. The plain anvil type requires a fairly heavy foundation of concrete suitably reinforced, and in making a choice of machines this extra cost should be taken into consideration.

The principal defect in jolt ramming is that the sand always packs in a downward direction, and will not fill underneath any projections. This defect can be met to a large extent by preliminary ramming under such projections, but even then a falling away takes place, increasing according to the number of blows given to the mould. Where possible a good plan is to leave a small opening in the side of the moulding box opposite any projection, through which the sand can be rammed under it after the final jolting. A little study of any job will always overcome these small difficulties, and I have no hesitation in saying that the future of the jolt-ram machine, especially in aluminium foundries, is assured.

Discussion.

In answer to Mr. Woods, on the question of the pressure which had been put on castings that were handed round for the inspection of the members, Mr. Gaunt said they had been tested at 25 lbs. Some more successful ones, cast at a lower temperature, had been subjected to 250 lbs. without any sign of leakage.

Mr. W. H. Aston, questioned how it was at higher temperature there was less shrinkage.

Mr. Gaunt said that metal cast at low temperature shrunk more and packed itself into a smaller space, thus making a sounder casting. He hoped to extend his experiments by taking microscopic sections in order to find out actually what is the structural difference in the two classes of metals. In outward appearance they seemed identical, but he believed at the higher temperature the metal absorbed the gases from the air, and, in cooling, these gases prevented the metal sinking into a solid mass. That accounted for porous castings.

Mr. Woods contended that the same metal which Mr. Gaunt had said was porous through overheating, would, if poured into a chill, be perfectly sound. He had proved that twenty-five or thirty years ago, when aluminium was first produced under the Webster process.

Mr. Gaunt said he had been buying, on the instructions of the Ministry of Munitions, a lot of old metal for remelting. In melting borings and turnings there was always a tendency for them to go down quickly, and the heat rose. Some bars cast in chill moulds would break in two directly they were dropped on the floor, whilst others would bend double before they would break. He believed the trouble in brittle bars was due to overheating during remelting. Nevertheless, it was a very interesting point that Mr. Woods had raised, and whilst he was supplementing the Paper by the micro-sections he would take the opportunity to overheat some metal and make both a sand casting and a chill casting with it.

Mr. Woods said the same thing he had indicated with regard to aluminium would be found with zinc.

Mr. W. Ellis expressed his surprise that the author in the Paper said that risers were better than chills. In dealing with some crank-cases he knocked the heavy risers off and put in chills, and found them much safer.

Mr. Gaunt said he had given this point a lot of consideration. In the first experiments he had no facilities for removing the runners except by sawing off the ends, and as far as possible he tried to do away with all risers and put in chills. In fact, the whole mould was simply a mass of chills. He admitted he got sound castings, but since he had facilities for removing the risers he had dispensed with all chills on crank-cases with the exception of three. There were only three chills on the crank-case top half, and the castings were perfectly sound. He contended from that that risers were more useful than chills, because with a chill there was always the risk of a blow.

Mr. Stone said his firm had done hundreds of thousands of gear cases in aluminium, and he

believed that there were only two risers and two runners. These castings were very seldom returned for blows. What did Mr. Gaunt call a good tensile test for a 92:8 alloy? He had one test which showed 9.5 tons tensile.

Mr. Gaunt replied that the tensile for a 92:8 alloy should be in the region of nine tons, depending on the melting and temperature at which it was poured. As to gear cases, at the present time he had six risers on gear cases; they were heavy cases for 35 to 40-h.p. engines, and no trouble was experienced. When using chills, however, he did have trouble. He warmed them and tried coating them with resin and brushing them over with paraffin, but occasionally there was trouble. Dusting the mould with French chalk seemed to do away with a lot of the trouble from blows, but even if they got only one blow in a month's working, it was worth while taking steps to remove the cause. It must be remembered that aluminium casting practice was very recent, and at the start the man who could make a successful casting was a smart man. Now the metal was certainly very much better, and there was no need for the chills that were required in the early days. The metal was much purer and cast better. For 50 per cent. of his work he did not use chills at all, yet he always got sound castings.

Mr. Woods thought the riser more reliable than the chill, because there was no fear of the top rising as with a chill.

Mr. Slater asked whether Mr. Gaunt agreed with placing the chill at the bottom or top, say, of a boss. His experience was that a chill would produce a blow-hole unless some preparation was put upon it to protect it from dampness. A little plumbago, china clay, and core gum, mixed and rubbed on to the chill, and polished dry, stopped dampness on the chill, or, even if dampness did settle, it was possible to wipe it off. Personally, he thought putting the chill on the top of the casting was far better than putting it at the bottom. With regard to running on top, his experience was that it was detrimental as regards the risers. Chills and risers together were successful, especially in the case of a boss, where the section above the boss was thin, and the section below thick. The chill would densify the metal at the bottom, where a riser could not feed the boss from the top, and by putting risers on a casting he believed that the pressure necessary to densify the metal was taken away, on the theory that the metal found its own level. Therefore risers, unless exceedingly large, were detrimental. Pressure and chills were far better in practice, both for malleable iron and aluminium.

Mr. Gaunt agreed that the chill was best on the top. In making sand castings the lightness of the metal must always be kept in mind. He believed in chills wherever it was impossible to feed with a riser, but if a riser could be used, then the head pressure was obtained better. The very fact that risers had been successful was sufficient to show that at least they were of some use.

Mr. Worton inquired what quantity of flux was used for a given weight of metal. Also, seeing that zinc chloride absorbs moisture from the atmosphere, was it detrimental to let it absorb that moisture.

Mr. Gaunt said the quantity depended on the treatment the metal had in the furnace. Heavily-oxidised metal required much more than carefully-melted metal. In fact, aluminium could be so carefully melted that it needed practically no flux at all. In casting from a 100-lb. crucible, a piece the size of a Brazil nut would be sufficient to flux away any oxide on the top. With regard to chloride of zinc, that did absorb moisture from the air, and became a watery fluid unless the air was excluded. He always kept it in earthenware jars with well greased cork stoppers. Provided the stopper was replaced in the jar, there was little trouble. If moisture was absorbed, he scooped it up with a spoon and put it in a piece of paper and dropped the paper on top of the metal. Chloride of zinc when bought usually had had the water driven off, but it did not alter the chemical composition to have some water.

Mr. Worton asked if it would be safe to use it in melting or remelting borings or turnings.

Mr. Gaunt replied that if he had watery chloride of zinc he should mix it with the turnings and borings before he put it into the pot. In that manner its action was far more effective, and helped melting, because, until the skin of oxide was broken, the metal would not flow together. Put into the pot with the turnings, it seemed to break up the globules of oxide. Then the particles of aluminium combined and thus increased the quickness of melting.

Mr. Worton inquired as to the best method of melting aluminium turnings and what would be a fair percentage of loss.

Mr. Gaunt said the best method was the crucible method, and the crucible should present as small a surface to the air as possible. If the furnace for melting aluminium swarf was a great, big open-mouthed thing, there was a tremendous loss through oxidation. Therefore the crucible was the best and, carefully worked, the loss should not exceed 10 per cent. Either a coke or gas-fired furnace should be used, and he would not recommend anything less than a 1,000-lb. crucible, a big crucible into which the aluminium borings could be shovelled and not put in piecemeal. With a small furnace there was very little result for a lot of work. The crucible should never be completely emptied; there should always be a fair amount of aluminium left in the pot. For best results he recommended that at least half the metal should be left in the crucible and the metal removed from time to time as the crucible became full.

Answering further questions as to the use of the reverberatory furnace, Mr. Gaunt said his experience was that wherever there was contact with the fuel or with the flames the aluminium suffered from deterioration. Better results were obtained from a crucible than from the reverberatory furnace.

Mr. Worton said he had found hardly any difference in the metal melted from turnings in a reverberatory furnace if the chemical composition was all right. The tensile was very much the same as when the crucible was used.

Answering Mr. Ellis, who asked whether he used wooden or iron boxes, Mr. Gaunt said that in the case of small work he used iron boxes, but with large work he used wooden ones for convenience of handling.

Other questions having been put, Mr. Gaunt said the question of the occlusion of nitrogen in metals had received some consideration, but not much in the case of aluminium. Nitrogen, for a long time, was undiscovered, and then it was suddenly blamed for all the faults that metals have. It would be interesting to know how far it really affected aluminium, but personally he did not know anything about it.

Mr. Willis, speaking with regard to "drawing" of cast aluminium, said the same troubles

were experienced with brasses. He remembered in his early days being asked to cast a brick in lead. That was a real problem to anyone who had not considered the points. On account of the drawing, unless there was plenty of feed behind the gate, a successful job would not be made. That was the problem with non-ferrous metals, and more especially aluminium. In his opinion a riser was best and safest, because with chills there was great difficulty in keeping them dry. The theoretical and practical point was to feed the heavy parts after the lighter parts had set.

At the conclusion a hearty vote of thanks was accorded to Mr. Gaunt.

Testing Refractory Fireclays.

At the recent annual meeting of the American Gas Institute the Committee on Refractory Materials presented a short report, according to which very satisfactory progress has been made in the determination of the conditions which refractory materials must meet in practice. Determination of reliable and practical methods of making the desired tests has been undertaken by the United States Bureau of Standards, and it is confidently expected that this work will be concluded during the coming year. At the suggestion of the Refractories Manufacturers' Association, the Bureau of Standards has been requested to continue further some experiments looking to the development of a high-clay brick possessing the characteristic of ability to withstand considerable load at temperatures up to 1,425 deg. C. with only slight contraction. Characteristic samples of bricks, available in various districts of the country, have been sent to the Bureau, where the characteristic expansion curve and thermal set of each will be determined. By this means it is hoped to be able to assist in making the proper selection of materials for various purposes. A sub-committee has under investigation the subject of refractory cements, determining the functions which they must perform, and gathering whatever data or experience is available. Professor Bleininger, of the Bureau, has given some results of experiments to the Engineers' Society of Western Pennsylvania. In particular, five well-known European fireclays (one open and four dense burning) imported by the United States in considerable quantities have been investigated with respect to porosity. With increasing temperature the viscosity of refractories decreases—we are told—and this softening is the greater the larger the amount of fluxes present. It had been suggested, therefore, that the deformation at certain temperatures and under given load be used as a criterion of the refractoriness of firebricks. From the data recently obtained by the Bureau of Standards it follows that the softening of the bricks becomes clearly manifest at 1,350 deg. C., which seems a suitable temperature for this test. The load to be supplied should not be greater than 40 lbs. per sq. in., and not less than 25 lbs. The relation between the deformation temperature T and the load W in pounds per sq. in. is expressed by Mellor's equation $T = Ce^{-kw}$, where C = deformation temperature of specimen without load; K = a constant, the numerical value of which depends upon the particular clay, and e = exponential constant. It was found that the more silicious the clay the less the difference between the deformation temperatures with and without load. On the other hand, the more the composition of the material approaches that of the pure clay substances, the greater is the difference between the deformation temperatures with and without load. It is possible, however, to produce high-clay firebrick showing excellent resistance to load conditions by using a mixture containing as high a percentage as possible of calcined No. 1 fireclay and a very refractory bond clay. Such bricks have been made under the direction of Professor Bleininger, and were found to possess an exceedingly small contraction with a load of 50 lbs. per sq. in. and at a temperature of 1,350 deg. to 1,400 deg. C.

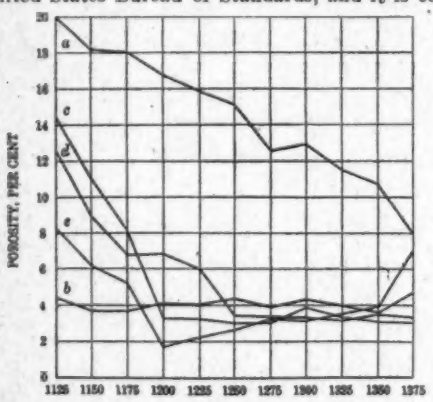


DIAGRAM SHOWING BEHAVIOUR OF ONE OPEN AND FOUR DENSE BURNING FIRECLAYS.

POWER COSTS FOR ELECTRIC FURNACES.—The question of power costs for electric furnaces took up considerable time at the recent Conference of members of the American Chemical and Electro-Chemical Societies. Mr. Morgan Smith, of the Detroit Edison Company, said that it was the ambition of his company to produce electric power with steam plants at such a low cost that it could not only compete with water-power current but could undersell it. He intimated that the time would not be far in the future when this ambition would be realised. Professor Richards thought the power question was a secondary one with most electric furnaces, except when making plain low-carbon steel to compete with open-hearth. Mr. Berry said the power companies did not fully appreciate the value of the electric furnace industry to them. Mr. Crosby said the central stations have been investigating the question more fully during the last three years.

IRON AND STEEL INSTITUTE.—The Secretary (Mr. G. C. Lloyd) informs us that the annual general meeting of the Institute in 1917 will be held at the Institution of Civil Engineers on May 3 and 4, and the autumn general meeting in the same place on September 20 and 21. He also calls our attention to the fact that a new class of "Associates" has now been established by his Council, elections to which class will take place by ballot in the usual way at the general meetings. Candidates for this new class must be persons not exceeding 24 years of age, and have one or other of the following qualifications:—(1) Students of metallurgy taking courses at a university, university college, or technical school. (2) Pupils or apprentices to metallurgists or engineers, or in metallurgical or engineering works. (3) Persons employed in some practical or scientific capacity in metallurgical or engineering works. Written recommendations, on a form to be obtained from the Secretary, must be signed by not less than three members, and forwarded to him at 28, Victoria Street, Westminster, S.W. Associates over 21 years of age, if qualified for membership, may, on application, be transferred by the Council to full membership.

Some Experiences in Steel-Foundry Practice.*

By T. Brown.

When first trying to make steel castings I found to my surprise that the ideas and methods were vastly different from those associated with ironfounding. It is quite a simple matter to make a "waster" casting, and wasters from such causes as are not thought about in the iron foundry. I remember my first experience in helping to make a locomotive wheel centre. Great preparations had to be made in the mixing of the sand with sawdust, also special care in the ramming of the mould. I could not understand the idea of having such a large riser on the boss, almost equal to its diameter. The mould, when finished, was taken away, put into a stove, and burnt (as I thought), taken out again, washed with black lead, and then tarred all over. It was eventually closed up and cast, and a few moments afterwards was knocked all to pieces with steel bars and hammers, for the purpose of allowing the wheel to contract, and so prevent it being pulled. Afterwards I was surprised to see that the casting *was* pulled, not only at each arm end, but on several places on the rim also. Instead of actually releasing the resistance to contraction, they were breaking the wheels before they had arrived at the stage of solidification.

Some time later I was working in another steel shop, where, along with other castings, wheel centres were being made, and the same methods were being used for releasing contraction. But one day a thing happened that caused a surprise. Whilst casting some centres the steel in the ladle gave out on the last one to be cast; there was just sufficient to fill the mould without putting any in the head for feeding purposes, and as it was known that it would not be of any use, it was left untouched. The surprise came when the wheels were finally knocked out, for although it was short run, it was found to be the only one in the cast that was free from any pulls whatever. From that day onward no more wheels were knocked out for liberation purposes. Causes of trouble in making steel castings have often been found out by means of a waster.

Another instance of a steel casting that caused a lot of trouble, some years ago, was a marine cylinder cover. The first one that was cast in the shop was found to be pulled around the outer flange, where it was attached to the body of the casting, causing it to be a waster. On the second attempt, the foreman ordered a much larger fillet to be put on where the previous one was pulled, and when the casting was dressed no signs of a pull were visible as on the previous occasion; but when it got to the machine shop it was discovered that the putting on of this extra fillet necessitated the top of the flange being machined, to get a flat surface for the bolt heads or nuts, and when the machineman was taking the last cut off, a hole developed in the shoulder of the flange. Upon searching there was found to be a cavity all the way round. Of course, the average foundryman to-day would say it was only what might have been expected. (See Fig. 1.)

The larger the fillet, the more dangerous it is to the casting unless special precautions are taken. If this particular casting had not been machined, the probability is that the defect would not have been seen or found out, but still it was there. Engineers or designers of steel castings should reduce corners or fillets to a minimum, and if strength is required it can in most cases be got over by attaching brackets, which would help the foundryman to secure a sound casting (Fig. 2).

About 26 years ago I was working in a steel shop, and an order was placed for a ram for a battleship. I think it would be about the first, of any great weight, to be made. It weighed over 20 tons, and at the nose was 16 in. thick. A good mould was made, and we had a good cast. Everything went off all right, but after some time, when it was thought the steel was set, a start was made to liberate it. After removing the weights

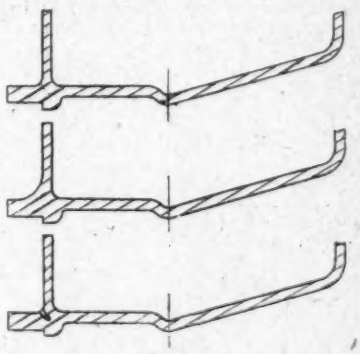


FIG. 1.

and getting the boxes off (taking up about one and a half hours after casting), a start was made to dig out behind the drawbacks, and to loosen all core irons as far as possible. Twelve to fourteen moulders were engaged, and quite as many labourers. It was cast about 10 a.m., and we did not leave it until 2.30 a.m. next morning. We were told to get the inside out, and as near to the casting as possible, but wherever we reached the casting we found it had gone blue, or in some cases black red. I believe the general idea was to stop it from pulling.

Now it is quite reasonable to think that we could not have got at that casting till it was set, or if we had, the steel, being fluid, would have run out somewhere, and I have, from a careful study since, and having had the superintendence of similar castings, come to be thoroughly convinced that a casting will not pull after it is set. It will only tear asunder at the critical stage of solidification, and, if a carefully designed casting is tied together with a well thought out system of brackets, as are generally used to-day in steel-foundry practice, almost any casting can be successfully made free from pulls owing to resistance; but a carefully prepared mould will have to be made, one strong enough to resist the pressure of the liquid steel and the heads above the casting, and it must also be so light that no practical resistance is there when contraction first takes place. I do not wish to

* Read before the Sheffield Branch of the British Foundrymen's Association, November 4, 1916.

assert that liberating can be done away with altogether, but I do think that it is only necessary to keep a casting to the shape required, by allowing free contraction.

There are other causes of castings pulling, unless very particular care and study is given to the job before putting the work in hand. For instance, a casting of an even thickness will pull sometimes, and at first one cannot understand why, until, perhaps, after some careful study, it is concluded that it must be owing to the position of the mould whilst being cast or to the way in which it has been run. There are times when a casting, such as a valve or pipe, is found to have pulled right on the top, and the only reasonable conclusion is that, whilst the steel is rising up each side of the core, as it is being filled, the steel has got somewhat chilled, and when it has met again on the top of the casting its fluidity and temperature are so far decreased that it could not properly unite and mix, thereby causing a weak place, and as soon as contraction takes place it parts asunder.

As to the use of chills, personally I do not care much about them, but I confess that they can be used on some castings to advantage, as in chilling facings, small bosses on valves, or small projections on other castings, where the thickness of steel is greater than the walls of the casting; but in all cases the chills should be in one piece, and entirely cover the part to be chilled.

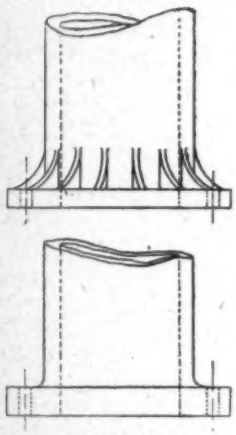


FIG. 2.

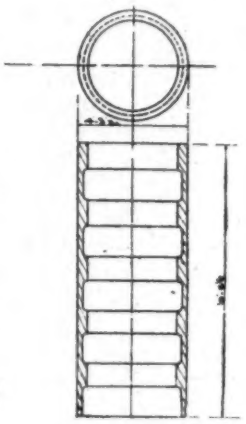


FIG. 4.

My experience in first seeing chills used was on an hydraulic cylinder, which had a thick belt running all round it. The idea was to cool this belt quickly and bring it to about the same temperature as the walls, so as to avoid piping. The chills were made in segments, placed round the pattern, and rammed up in the usual way, and touching one another, but as the chills were not machined the joints were not a very good fit. The result was that when the casting came out it was found to be pulled, or cracked, up the belt at the places where the chills met each other, and pulled to the depth of the machining allowance, and in some places deeper. It is my opinion that if chills are put on in pieces, the same thing will almost always happen.

Another experience in chilling a casting was with the side for a forging press. Along one side of this casting ran two slides the full length, about 14 ft. long, and about 8 in. by 3 in. in section, standing out from the walls, and owing to the design it was necessary to mould on its edge. To get those slides solid it was suggested at first to use short cast-iron chills, but my previous experience would not admit of this; besides, a great difficulty arose as to how to keep them in place. so it was eventually decided to put a chill the full length. Suitable forged bars were secured, 8 in. by 5 in. thick, and placed along the bottom two slides. The mould was proceeded with, suitable allowance made at each end of the bars for expansion, which, as we thought, would be all right. But when the casting came out we found there was one thing we had not thought about, and it was the fact of the bars only getting hot on the side next the casting. The result was that the bars expanded on that side only, causing them to bend or camber toward the casting. Each embedded itself in the facing at the centre of its length to the extent of about 1¼ in., and as there was only ½ in. on for machining, it left a deficiency of ¾ in., and which we were afterwards allowed to weld on, so as to save the casting.

At the present time cast steel valves for steam service seem to be in favour. I have had hundreds through my hands, and, I venture to say, with a fair amount of success; but every time we get a new order, the difficulties seem to increase, as the designs alter so much. What with the amount of divisions and seatings inside, and the fittings that

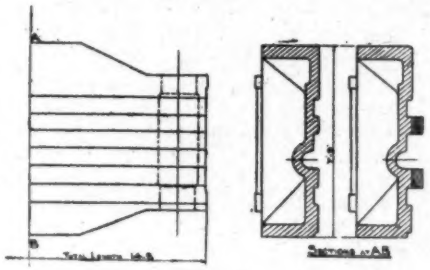


FIG. 3.

are attached outside, one hardly knows where the valve part leaves off and the fittings begin. In some cases one can hardly see valve for fittings, i.e., feet and brackets attached to the body.

There are many steel castings required, which I venture to say are impossible to make, without the addition of a lot of superfluous material, i.e., material put on to ensure a good sound casting, and which must afterwards be machined, or otherwise cut off. I have in mind now rolls and mill pinions. Whilst I know that in the iron foundry it is not impossible to make rolls or mill pinions with the wobblers cast to shape at both ends, and get a solid casting, yet it is not so with steel. Owing to the enormous expansion of liquid steel it is necessary, in order to be successful, to cast it on end, and to have a large amount of material on the top end, almost equal to the diameter of the body, also a head above the total length of casting to ensure solidity. Now all this has to be machined off again, and the wobblers cut out to bring the casting to what is required. That is what I mean by superfluous material. I have seen rolls cast flat, but they have not been a success, the amount of head required being anywhere from 120 to 150 per cent. more than the actual weight of the casting, and machining allowance almost equal to one cast on end. Mill pinions of a small size are

made in steel with the wobblers cast on both ends, but one that has been cast solid at one end is to be preferred.

Another type of casting that has been a source of trouble to some steel makers, and in which it is necessary to use superfluous material, is the marine stern tube (Fig. 4). If this is cast on end to the section shown, it could not be a good casting. At some places they have been made on their sides, but with what success I do not know, and I should never attempt it myself. The extra work required in preparing the mould and the core, and the means to be adopted to keep the casting in one piece, when contraction takes place, also the extra work required in the fettling shop would cost more than making a straight tube and machining the recesses out, notwithstanding the excess material; and besides, one would be more sure of a good casting.

Now as to castings breaking. A few years ago, when turbine drum centres (or what are commonly called turbine wheels) were first made, the first set of castings of any large size that I had to do with was about 7 to 9 ft. diameter. They were considered to be a delicate job from the steel-founders' point of view, owing to the amount of machined surfaces, and because they had to be a perfectly

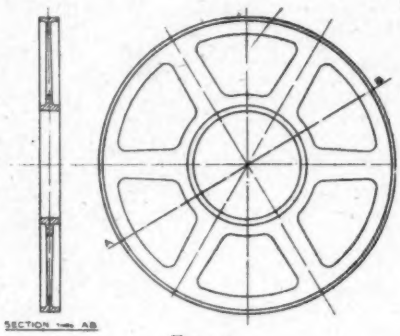


FIG. 5.

clean job, equal to forgings. With these castings we were fairly successful, but shortly after this an order was placed for a much larger and heavier set, ranging from 10 to 12 ft. in diameter, and weighing from 15 to 20 tons. We followed as far as possible the same lines as in the first set in which we had been so successful, but we were not long before we had a setback. We had a good cast with the first wheel, which was a large one. It came out all right, was put into the annealing furnace, and was apparently all right when it was taken out, but three days after it had been in the fettler's hands it flew, breaking through the rim, and also three or four arms. Drawings of the previous ones were compared with the ones under consideration and we found there was a good deal of difference in sectional design. Owing to the small diameter outside and the large diameter of boss in the first set, and also to the arms being at an angle from top of boss towards the rim at the bottom, in looking at section through the centre it looked quite a conical shape, but not so in the larger ones, for although the arms were somewhat sloping, they were almost at right angles to the boss, owing to its greater diameter.

We knew that great risks would have to be taken if we again attempted to make them as they were, and as it was such a large and costly job, we decided to point out to the engineers our difficulty, and they asked for suggestions. We suggested at once that the wheels should be split at the boss, and they would not agree to this, but it was agreed to split the rim, which got us out of our difficulty, and after this all large turbine wheels were designed with our suggestion embodied, which relieved other makers also of similar troubles. Out of hundreds of turbine wheels made since that time, not many (if any) above 4 or 5 ft. diameter with arms in, have been made without being split in the rim.

Another wheel for turbines which has been the source of a lot of trouble at various times is shown in Fig. 5. These are frequently called rotor wheels. They may be anything from 8 to 11 ft. diameter and have to be machined all over, and must necessarily be perfect, and to the steel-casting maker it is obvious that owing to the section as shown, he will have to put on superfluous material to make sure that no piping is found when the machineman is just about to finish it. But in spite of all precautions some of them did break.

I will explain what I feel certain was the cause of breaking, as the same cause breaks a lot of other wheels, not only in the steel foundry, but also in the iron foundry. Imagine a wheel with a very heavy boss, which is doubtless necessary, but which

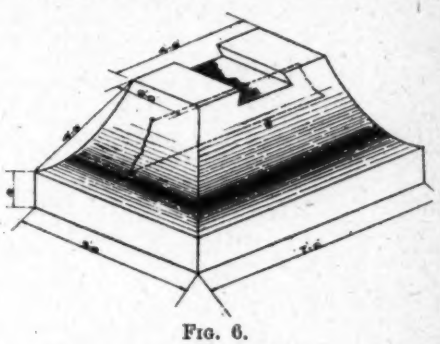


FIG. 6.

only requires a very light rim and arms. This wheel is to be secured into a drum of some sort. It is impossible to get both the boss and rim to cool equally at the same time, so the position is that the rim being thinnest would have finished cooling first, and would contract to its position, before the boss is cool, and therefore before it has finished contracting; or in other words, the boss will get yet smaller and cannot do that without breaking itself away from the rim; so it is reasonable to think that if it is at all possible to keep the boss and rim at fairly even thicknesses so that they will cool and contract evenly, there will not be much trouble. The same thing applies in the annealing process; one should be as careful as possible in cooling down, though it is almost impossible to get perfectly uniform cooling.

Now, reverting to the breaking of the rotor wheels, as it was impossible to have these wheels split (and remembering the conical shape of the turbine wheels mentioned previously) we found that by adding extra machining at the top of the arm at the boss, and by reducing the thickness at the other end, near the rim, and applying it underneath, we could get a certain amount of cone on this wheel. This was found to relieve us of a lot of trouble and, as proving that the cone shape was helping us, we found that the boss had so far

lifted in contracting that it almost ran away with the machining allowance on the bottom side.

This question of cooling does not only apply to wheels but to large blocks of steel. A case occurred with a hammer block, which weighed about 36 tons. After being stripped and cleaned, and about two weeks after it was taken out of the sand, it was found one morning to be cracked (Fig. 6.) The peculiarity about the fracture was that the casting was not broken in two pieces, but the crack went right through the centre of the block, which was about 5 ft. deep, and the crack extended about 2 ft. in the centre, leaving 18 in. solid on each side of crack. A hole was drilled right through the block to stop the crack from extending further, and it was subjected to a severe drop-test and proved not to have cracked further. It was eventually placed under the hammer it was intended for, and as far as I know is still being used to-day.

Another instance of trouble which occurs to the foreman in most steel foundries, is that he does not know what weight of material he has in his ladle before proceeding to cast. At the shop where I am working, we certainly save a great deal each year in this respect, by having a weighing machine, which we attach to the crane before hanging on the ladle, and before the molten steel is tapped into the ladle.

The scrap and moulds wasted was a big item some few years ago, so we consulted a firm of weighing-machine makers, who made one as desired. I believe it was rather costly, as they had to take into consideration the temperature it would have to stand, without affecting the balance, but, however, they succeeded, and it has saved its cost many times over in preventing moulds being spoilt by being cast short.

It may be of interest to say a few words about foundry tackle. I know it is very difficult in some shops to get hold of any, but a few pounds spent on good standardised tackle means many more pounds saved in a short time. I adopted a system, as far as possible, of standardising boxes and everything I could, for foundry use. Box parts, for instance, which are cast in one piece, are made to certain sizes, round or oblong, and mostly just in what are termed "middle parts," i.e., parts without any bars cast in. Flanges are cast outside, top and bottom, and each part is drilled to template for pins. These boxes can be used singly, or put together.

Bottom plates are cast of suitable sizes to be cramped or bolted on, and can be used for bottom parts or drags. To contend with heads or risers on different jobs bars can be laid across and fastened to the flanges, or suitable grates can be cast and fastened on for top parts. In a steel foundry they must be of suitable strength, for more than one purpose; for instance, they must resist any twisting out of shape, whilst being turned over, or otherwise slung on cranes, also they are frequently going through the drying stoves and heated up to a high temperature, almost red hot at times. Strength is more than ever required when the mould has been cast and then the casting has to be knocked out.

Owing to greater strength required in the boxes they are of greater weight, and owing to this fact cranes are more used in a steel shop than in an iron shop. Boxes of only very small sizes are lifted by hand. Now as to larger or built-up boxes; these are boxes which are built up from loose sides and ends, and are, as far as possible, interchangeable. If a box side breaks, as they sometimes do, it can soon be replaced by another from the stock yard. Box sides are made in various lengths, measured in feet from 8 to 14 ft., and in 2 ft. from 14 to 18 ft. The depths of box sides and ends are 12 in. and 24 in., and end plates of various lengths from 4 ft. to 11 ft. to suit sides. So no matter what useful sized boxes are required, we are able to build one. All holes are cast at equal distances and sizes for bolting purposes, and the same applies to the holes in the sides for loose bars. It is well known in steel-foundry practice that there are many occasions when two and three or even more parts have to be carried together for stoving purposes, so it is our practice to have sides and lifting handles strong enough to meet any requirements. We have also cast-iron pockets for lengthening purposes, 12 in. square, 12 in. by 24 in., and 24 in. square, so that if any box of a particular length is required and cannot be spared, another shorter one can soon be lengthened by attaching the pockets. Fig. 7 shows some examples of box parts.

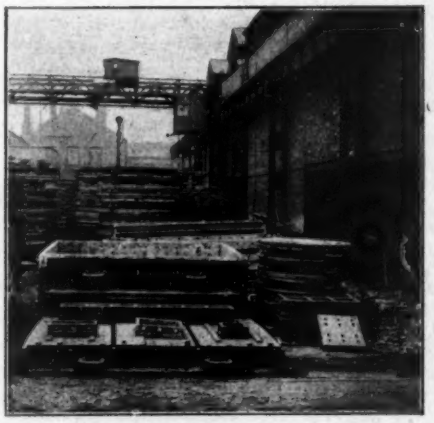


FIG. 7.

Another sort of tackle of great interest is spindle work. It is a great mistake in any foundry to have spindles, arms, and plates of various sizes and shapes; it is best to have them standardised. In my own shop any spindle will fit any plate, and any arm will fit any spindle, the only variation is in the length of spindles and arms, and the spindles are allowed to revolve in the centre plate. In some shops it is the practice to have the spindles a fixture, and the arm with board attached riding on a movable collar, sliding over the spindle. My experience convinces me that with this system a lot of mistakes can be made, owing to the striking board being so free in the moulder's hands, and especially in steel foundries, where it is the practice to ram the sand very hard on a mould, and then scrape it off with the board. With a loose arm the board is liable to ride over the sand, or, on the other hand, by putting pressure on to cut the sand, the board is pressed too far down and the mould is consequently out of shape. This may not apply in metal shops, as generally the only resistance is wet loam; but if the spindle is fixed rigid in the centre plate, and only allowed to revolve, and the arms machined to fit the spindle, and then fastened with a set screw at the back, there is nothing to get out of place. The striking

board is squared to fit up against the spindle, and can be checked by measurement or gauge, from the spindle to a standard distance on the board, which is marked before using. By being a perfect fit in the centre plate, and only allowed to revolve, it becomes impossible for the moulders to lift the board up or press it down, and besides it does away with the time of levelling the spindle plate, as it can be laid level enough to work with the eye. Our method is to have the spindle tapered at the end which fits the plate, to a given angle, by machining. The plates are of cast iron, having been cast around the spindle, thereby saving the cost of boring, and, as before said, they are all interchangeable. It does not matter whether a long spindle is required or a short one, and as a plate is in a convenient position in the floor, it is not necessary to remove it. (Fig. 8.)

Good chains are a great asset, and should have every care. If more than one chain is used on a job, great care should be used to see that the weight is equally distributed on each leg of the chain. When one considers the hundreds of lifts of such various weights which are handled daily in

FIG. 8.

a foundry, and with so much life at stake (and even without damage to workmen there may be serious losses in case of breakages to material and loss of valuable moulds), the necessity for great care is obvious. It is quite a simple matter to know the strength of chains required to lift a certain weight, but it is not quite so simple to judge the weight to be lifted, but with more care, accidents could be avoided.

Discussion.

MR. JOHN WATSON said he quite endorsed what Mr. Brown had said about the necessity of engineers taking a lesson from steel founders. A great many of the founder's troubles were entirely due to the engineer's ignorance of what happened in the foundry. Among the slides which Mr. Brown placed on the screen was one of the end of an accumulator cylinder. The bottom half had no brackets on, while the top half had a lot. Mr. Brown did not say anything about the top half. In the speaker's opinion, steel founders went mad on brackets. They were a survival of the barbarous days when the founder could not trust the steel maker. He found that a great deal of trouble in the steel foundry was due to the moulder putting on brackets. In a great many cases they were dirt traps. They also acted, in his opinion, as instruments for drawing away the steel from the body of the casting. Very frequently, when he had seen a cylinder of that sort machined, there was a small hole opposite every bracket on the casting. He thought the steel founder should try to do away with brackets, and make his moulds so that the casting in contracting liberated itself. The same thing happened in cracks that took place in turbine wheels. Often a crack in a wheel was due not to the steel or to the design of the wheel, but to the way the mould was made, and very often to the way the core was made. Steel makers had a great habit of putting irons in cores. He thought this was overdone. The moulder who could make his cores with a minimum of irons, or without any at all, was on the right lines for producing castings without cracks. His experience was that about 2 per cent. of the trouble was due to the steel, and the rest to the moulder—thrown in, of course, with the designer, who, especially in valve castings, was the chief sinner. He was very much interested in Mr. Brown's remarks about the stern tube. His firm had had the same difficulties to contend with that Mr. Brown had, and they had cured the

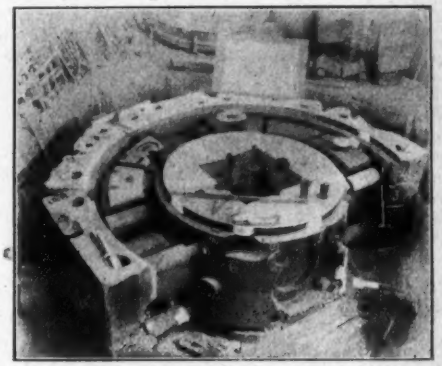


FIG. 9.—MOULD MADE ENTIRELY OF CORES, COMPRISING 122 SEPARATE PIECES. CASTING WEIGHED OVER 22 TONS.

trouble in exactly the same way. They had to make a plain cylinder, and then machine out the recesses. He was taught that by a very serious experience he once had in attempting to cast a stern tube with the recesses in. No trouble developed in the thin part of the tube, and when the job was finished it looked all right, and the tube was built into the ship. But when the final cut was taken out by the engineers in the thick part, they came upon a piped hole and a crack right in the inside. These tubes had to be cut out of the ship, causing great expense. Since then they had adopted the method described by Mr. Brown. One often received great help from seeing what other people did. He remembered once having a great deal of trouble with blank wheels of large and various sizes, in which the teeth were machine cut. When the teeth were cut it was found that, at the root of several of them, round the rim, there were draw holes. He went to the shop where they were being machined, and was shown some wheels that came from Germany. They were the roughest castings he had seen, and were not properly fettled (the arms were run short in many places), but they turned up beautifully

clean, with not a speck anywhere; the teeth were cut out solid, without a flaw. This rather worried him. They had another go at the trouble, but did not cure it. The second time he went back to the place a new consignment of wheels had come in from Germany. The manager remarked to him that there was a curious thing about these wheels which he did not understand. It was that the Germans only rough-turned half of the rim. Immediately he said that the solution of the difficulty occurred to him (the speaker). Half way down the rim from the top side they had put a wedge-shaped piece the whole way round the rim, getting an area on the top edge of the wheel of about four times what they had on the bottom edge. They then put their risers on the top of that. After casting, they put it in the lathe, and machined off the surplus metal, with the result that the whole wheel was found to be fed solid. His firm adopted the same principle, and had never had a bad wheel since.

Mr. J. R. Hydes remarked that his experience was with castings from 20 lbs. up to possibly 200 lbs., which was a speciality line, but it looked to him that the same troubles that came into a 20-ton casting came into a 20-pounder. He supposed that it was during the range of fluidity from the casting temperature down to solidification that the various and sundry pulls occurred. It seemed that when steel was put into a mould the whole of that steel remained liquid for some time, whether that time were five seconds or five minutes. He would like to ask the lecturer whether that was correct, and was a proper assumption to make in considering shrinkages and the way to counter them.

Mr. Brown, in reply to Mr. Watson, said he had the illustrations referred to specially prepared to show engineers how difficulties might be overcome by the reduction of the thickness of the flange and the addition of brackets. He did not know whether or not the engineers had at some time had a very bad accumulator cylinder that had given out, but the fact remained that they had gone on increasing the thickness of the flange. He considered that the more they increased the thickness of the flange the bigger defects they would get, while, by adding brackets to reduce the thickness of the flange, they would get safer castings. In answer to Mr. Hyde on the question of solidification, he said this all depended upon the thickness of the casting. If they had a heavy casting with a wall 3 ins. thick, and it was attached to another wall, say, 6 ins. thick, during the time that the 3 in. part was solidifying there was a certain skin set up around the thicker part that would perhaps hold itself to the thinner part, and no pulling or anything would result, because the skin was thick enough to hold it. But if they got a small casting, half an inch thick, and it was attached to another part of a casting an inch thick, it was done instantly. It did not take many seconds for the half-inch piece to solidify, and before the inch piece was set it began to tear itself away.

A hearty vote of thanks to the lecturer concluded the meeting.

Hard Soldering Flux.—The following liquid flux to be used in connection with hard soldering or brazing has been recommended:—Either borax or boracic acid, or a mixture of the two, used as a flux. If preferred the flux may be used wet by mixing with clear water, but the solution should not be made too dilute.

Aluminium Alloys.

At a meeting of the Scottish Branch of the British Foundrymen's Association on October 9, Mr. J. Ellis, the President of the Association, who was present in his official capacity, complimented the Branch on their work, and noted with pleasure that numerically the Scottish Branch was the strongest in the Association.

Mr. C. H. Desch, D.Sc., Ph.D., then delivered an address on "Aluminium Alloys." At the outset he referred to the growing importance of the subject of aluminium alloys. Aluminium, in its pure state, was a comparatively weak metal, and very difficult to cast solid; when alloyed, however, its strength was increased, and its casting properties were greatly enhanced. Recently a new term has been introduced into the specifications for light aluminium alloys which had regard to the strength compared with the specific gravity of the alloy. The term referred to was "Specific Tenacity," and this value was found by dividing the tensile strength in lbs. per square inch by the weight of a cubic inch of the alloy in lbs., as—

$$\text{Specific Tenacity} = \frac{\text{Tensile strength in lbs. per square inch.}}{\text{Weight of a cubic inch of the alloy in lbs.}}$$

There were many metals which could be alloyed with aluminium, but copper was the material chiefly used in this respect. Copper could be added up to 5 per cent., but alloys containing 3 to 4 per cent. were most common in practice. In an alloy containing, say, 20 per cent. of nickel, a strength of 7½ tons per square inch could be obtained, and by hot rolling this strength could be raised to 17 tons, and could still further be improved to 20 tons by cold rolling. Nickel, up to 5 per cent., was another metal which was used for alloying with aluminium. An alloy containing 4 per cent. of nickel gave a tensile strength of about 9 tons per square inch in its cast state, and this could be improved to 10 tons by hot rolling, and to about 12.5 tons by cold rolling. The high melting point of nickel compared with aluminium presented some difficulty in producing an alloy, but this could, to some extent, be overcome by first making a rich alloy containing, say, 20 per cent. of nickel and then melting this with the aluminium in the desired proportion.

The addition of copper to aluminium produced an alloy which was slightly more sensitive to corrosion than when nickel was the alloying material. No appreciable advantages were obtained by adding nickel to copper in combination with aluminium.

Zinc and aluminium gave a good casting metal; such an alloy might contain up to 20 per cent. zinc, and good results were also obtained by adding zinc and copper in combination with aluminium.

The lecturer explained that the difficulty experienced in melting aluminium scrap was due to an oxide which formed on the outside; he also stated that it was not safe to melt aluminium in a plumbago crucible, as the metal absorbed the carbon, and carbon was an undesirable constituent in aluminium. A number of slides were exhibited showing the microscopic structure of the various alloys, and explanations were given of the effect which the various combinations had on the strength of the material.

Machine Moulding.

At a meeting of the Sheffield Branch of the British Foundrymen's Association on December 16, Mr. John Little in the chair, a lecture on "Machine Moulding," was delivered by Mr. R. Carrick, of Shipley.

Before the business of the meeting was proceeded with the BRANCH-PRESIDENT made sympathetic reference to the loss the Branch and the Association had sustained by the death of Mr. H. Pilkington, of Sheepbridge, the original President of that Branch, and a Past-President of the parent Association. A vote of condolence was sent from the Branch to the bereaved family.

MR. CARRICK, in introducing his subject, remarked that he was not interested in the manufacture or sale of moulding machines, but with many years' foundry experience in all parts of the world he was convinced of the great utility of these appliances in foundry practice. At the works of which he had charge a large number of moulding machines were in use, and he extended a cordial invitation to members to inspect them.

In spite of the fact that founding was the foundation of the engineering industry, and that modern industry depended upon the foundry for a large part of its products, it was, he continued, surprising what a small proportion of the inventive genius that had for generations been busily engaged in the evolution of labour-saving machines had been devoted to foundry machinery. It was only within the last 25 or 30 years that moulding machines had been used to any great extent in this country.

Moulding machines could be classed under four heads:—(1) Machines that only ram the mould; (2) machines which draw the pattern; (3) machines that both ram the mould and draw the pattern, and (4) machines in which every operation is mechanical—sand-filling, ramming, pattern-drawing, and conveying finished mould away. The lecturer proceeded to deal in detail with the operations of these various types of machines, and illustrated their great labour-saving merits. Of the power machines he confessed to a strong preference to the compressed-air type as being the most serviceable and popular. With the introduction of jar or jolt-ramming machines there was a much wider range, and almost any size of mould, whatever its shape or size, could be dealt with, and did the work more efficiently and in infinitely less time, as well as saving the hard labour of the moulder. In his own experience a gang of two moulders and machine operator and one labourer had done the work of about six or seven floor moulders working under ordinary conditions. Unfortunately many foundry managers and employers in the past had not been as successful with machine moulding as they might have been, because, having installed the machine, they had not given the thought and expense they should have done to making the necessary tackle, and very often machines had been condemned and in many cases gone to the lumber heap when with judicious handling they might have become a valuable asset in the plant. Mr. Carrick emphasised the point that not only must care and thought be used in selecting the right machines for the work, but equal care and infinitely more thought should be used in making the necessary tackle. It was not to be inferred from this that it was always necessary to put down very expensive tackle in order to make the machines a success. One should be guided by the class of work, number required, etc., and many times it would be found that the outlay would be very little greater than for floor moulding. It was not only where there was much repetition work that the machines would be found advantageous, although it was in such work that their greatest utility would be found, and with the present tendency to greater specialisation their value would increase.

It could not be claimed that engineering practice in this country was in the forefront either in the manufacture or use of moulding machines. Many engineering firms that had equipped their shops with the finest tools and equipment that money could buy had shaken their heads when invited to spend a few pounds on foundry machinery.

Discussion.

MR. JOHN LITTLE (Branch-President), in opening the discussion, said he knew of one foundry that had been running for over 50 years, where all kinds of moulding machines had been installed, but after a comparatively brief experience had been allowed to go on to the scrap heap. That did not speak very well for the enterprise in the moulding trade in Sheffield, although there were places where such machines were largely used. There was, however, a strong prejudice against the machines on the part of the men. They seemed to think that the machines took work from them—although the same argument might as reasonably be applied against the typewriter or the pneumatic chipping tool. The fact was that the greater the demand for a class of work the more of that work there was for the men who did it, and there was no doubt that if moulding machines were more largely used the output would be larger, costs would be lessened and that would enable employers to get more work to keep the moulders more fully occupied. He knew, however, from experience at the men's meetings that the men would not have the machines, or, at any rate, would not encourage them; but theirs was a very short-sighted policy, and the time had come when it must be combated, for if this country was to hold its own the costs of production must be cheapened.

A MEMBER asked if Mr. Carrick had any experience of jolting machines for deep boxes, where it was necessary to dry the mould. In using the jolter with a very deep top part and drying the mould and afterwards using a lifter, was there not a tendency to break the mould when rammed and dried?

MR. WATSON said he personally was a great believer in moulding machines, but had not seen one which, for the steel trade, was in his opinion satisfactory from the point of view of the construction of the machine. He had not seen one strong enough to do the work in the steel trade, and that was one cause of prejudice against the machines. Makers said the machines would do the work, but after a short experience they were found to break down, and if Mr. Carrick could do anything to persuade the makers to learn the real requirements of a steel foundry, and to make their machines accordingly, he would do the foundry trade a great service.

Mr. Darley believed that one of the greatest difficulties with regard to steel foundry work was that a special compo of sand had to be used on the face and if there was a top mould the moulder had to either do a tremendous amount of ramming or run the risk of getting the backing sand on to the face of the casting, which was very detrimental to a steel casting. Personally, he would like to know of a good machine with a good jolt rammer that would stand steel work. He did not use the stripping plate because it was found too expensive, and he had not found skilled men, let alone unskilled men, who could make a stripping plate. They simply drew the pattern by hand and found it possible to do a great amount of work that way.

Mr. Hyde said that as a rule the engineer abhorred sand and would keep as far as possible away from it, and consequently he had not been attracted to the foundry as offering scope for his inventive ability. They would find that no matter how well a machine worked in its first few months it would begin to develop slack places, which upset its nice working. The top and bottom parts had to be rammed separately, so that the moulder was absolutely dependent on the pinning system for getting a good joint, and that was a source of trouble. The pins might work splendidly for the first month, but after that, with the corrosion due to the watering of the boxes, and the inevitable knocking about, the joints very soon began to give trouble, and he would therefore be glad of any advice on the pinning system. Further, he would like to know if Mr. Carrick advised the machining of the box joints? In regard to the supposed saving by the use of power, he would admit that by the use of pneumatic power there might be a saving in moulders' wages, but it must not be supposed that the power was got for nothing. In his experience it cost something like 9d. per hour for pneumatic power for even a small size of machine. The lecturer had not alluded to the pneumatic rammer, and he (Mr. Hyde) thought that the introduction of this labour-saving device might, at any rate in Sheffield foundries, usefully open the way to a more extended use of moulding machinery. He felt sure no workmen would long object to machinery which would save the laborious toil and trouble of stamping round a mould for three or four hours on end. Any man got heartily sick of such labour and if by the turning on of a tap it could be avoided, and the work be done better, he could not believe it would be opposed. Another trouble in connection with the machines was the carrying of sand to them, and he thought those machines which were on wheels and could thus be taken to the sand heap had a considerable advantage in this respect.

Mr. Carrick, in the course of his reply, said he had experienced no difficulty in working with deep boxes where the mould had to be dried. He had successfully rammed two feet deep with jolt ramming, where there was no overlapping. Although he had had no steel-foundry experience, he did not think, from his study of the problems, that there should be any real danger of the back sand behind the compo reaching the face if the mould was made with due care. If the job was a very deep one it was quite feasible to jolt it twice. He thought it would be only the result of carelessness on the part of the men putting in the sand if the back sand got to the face of the mould instead of the compo. Theoretically, as well as in actual practice, the jolting was infinitely better than hand ramming, because it effected the exact process required, every particle of sand going down to its correct position instead of one layer coming on the top of another and so forming a series of joints. He did not think Mr. Watson should find any difficulty, even in regard to steel moulds, because they required them harder in steel than in iron. In regard to the strength of the machines being inadequate to steel work, that was purely a matter for the makers, but in the later machines they were putting steel frames for the bumper and cases. He had found it was generally necessary to make special boxes, and adopt the rule to give the bars considerably more taper than for hand work. It was absolutely essential to keep the box part thoroughly clamped, and if this was done he did not think there could be any displacement. On the question of the pinning system, his experience convinced him that the best system was to have loose pins instead of fixed pins. They jigged all their repetition boxes and cast good, deep lugs instead of the ordinary standard lugs, 3 in., 4 in., or 5 in. thick, with a straight hole through, and made hardened steel pins, 1¼ in. diameter, with just a little taper at the end, so as to get a running fit. If the boxes were got level they never got such a thing as a twisted joint. Since the adoption of this method he had had no difficulties, and he found it cheaper, in the long run, than fixed pins.

Replying to further questions Mr. Carrick added that, in his opinion, it was advisable where possible to machine box joints, He did not see why any foundry should not have as good class of work as the machine shop. As for compressed air at 9d. per hour, he considered this rather a "tall order," but even at such a price, if the power was working 20 or 30 machines, as it should do, it would not be excessively costly. His practice was to have near the compressor a storage tank so that there was little or no condensing in the pipes, and as all the machines would not be jolting at the same time he did not think it too much to allow 20 or 30 machines for such a power plant. With regard to the conveying of sand, his preference was to carry the sand by hoppers and bring it up by conveyors, and to keep the machines stationary. To run every machine alongside the job would demand a tremendous amount of floor space, and he thought future practice would tend in the direction of conveying the sand by hopper and feeding it down into the machine.

On the proposition of the Branch-President Mr. Carrick was heartily thanked for his Paper.

ELECTRIC FURNACE MANIPULATION.—Mr. Harry Etchells, in a lecture on "Electric Furnace Manipulation," recently given to the Sheffield Society of Engineers and Metallurgists, when dealing with the cost of smelting, remarked that even at the present comparatively high prices caused by war conditions, the electric furnace had proved a good investment to many users and an immense boon in the economy of steel production and the utilisation of waste. The war had shown us how to make ourselves independent of Swedish Bessemer imports and to convert into valuable steel the accumulation of nickel and chrome steel scrap. In spite of difficulties of manipulation, which still remained to be overcome, the electric furnace had a part of its own to play, and had come to stay. Prof. J. O. Arnold, the President, however, observed that if the electric furnace had come to stay, they would have to have cheaper current. That was one of the greatest obstacles to the development of the electric furnace in Sheffield, and it would have to be got over in some way.

Gronwall-Dixon Electric Melting and Refining Furnace.

At the recent Convention of the American Foundrymen's Association, Mr. John A. Cowley, in a Paper dealing with the Gronwall-Dixon electric furnace, described it as operating on a 2-phase system, energy being taken from 3-phase supply through two banks of transformers connected by

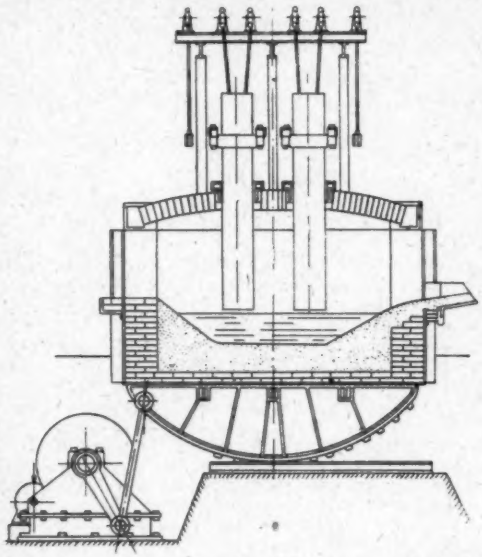


Fig. 1.—Section of Gronwall-Dixon Electric Furnace.

a modified Scott 3-phase to 2-phase connection. In units of five tons and larger capacities, four vertical electrodes are introduced through the roof. The bottom electrode is embedded under the lining of the hearth and is entirely protected from the molten charge. It therefore requires no water-cooling. In capacities smaller than five tons, two electrodes are introduced through the roof. The transformers are arranged to deliver a current at varying voltages, available as required by the operator. Each phase of the 2-phase current, which takes a balanced load from the 3-phase supply mains, is carried to a pair of the vertical electrodes, the bottom electrode being joined to the neutral point of the transformers.

Through a special arrangement of switches the arcs can be thrown in series, or in parallel, or in several intermediate positions between series and parallel. During the melting stage while the arcs are in series, the lower electrode accelerates the process by carrying a considerable proportion of current, as well as all the unbalanced loads, which in commercial operation are unavoidable. Because of this feature, the power input to the furnace may be increased over and above the amount it would be possible to carry without the bottom electrode. In subsequent periods of refining, recarburising, and introducing alloys, or for holding the bath, the voltage can be reduced, shortening the arc, thereby lessening the reflected heat on the walls and roof. This procedure prevents rapid destruction of the refractories. When operating with a short arc the parallel or one of the modified connections is used, passing a large proportion of current through the bath to the bottom electrode. By this method the proportion of current flowing through the lower electrode can be varied within wide limits. From the power companies' point of view this transformer and connection arrangement makes a desirable load. The transformer efficiency is 98 per cent. or over, the power factor is 92 to 97 per cent., and the service mains and power station are not disturbed by any serious surges. Small surges that occur during the melting period are absorbed by the interlocking of the phases by the transformers.

The furnace is cylindrical in shape and of the usual tilting type. The tilting operation is carried out through worm-driven connecting rods operated by motor drive through a reversing controller. The furnace is designed with two doors front and back. The front door is a combination pouring and charging door, the spout being removable. The use of two in place of three doors, as is customary on electric furnaces, reduces the heat losses. The roof is built up in a supporting ring from special shapes of silica brick; it is removable, and by providing a spare roof very little time is lost in replacing in case one is burned out. The electrodes are carried by an overhead support

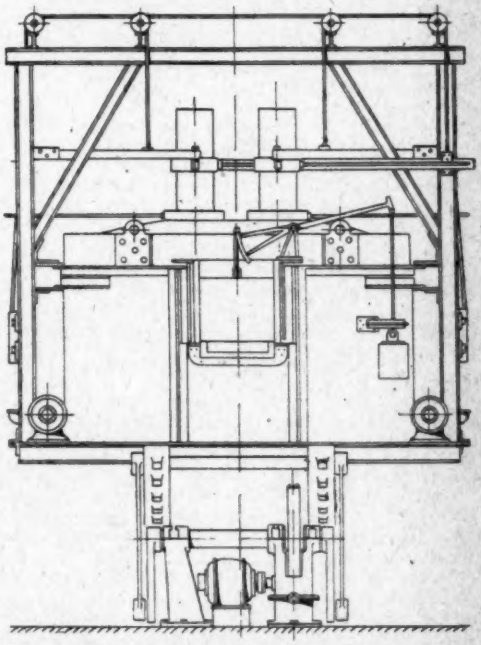


Fig. 2.—Elevation of Charging Side of Gronwall-Dixon Electric Furnace.

made up of I-beams. Their weight is taken up by a counterbalance to which the mechanical gearing for the control is attached. This control is operated by an individual motor for each electrode, which is energised through a system of contactors located on the switchboard, either automatically or by a hand-operated push-button station.

In a furnace installed at Detroit, of five tons capacity, up to August 1 last over 800 heats of alloy steel for automobile and aeroplane construction had been poured, and the results obtained had been so encouraging that an additional 10-ton unit was now being installed, and arrangements for still further additions had been made.

The operation of this furnace, continued the author, is continuous. The cold charge, consisting of various kinds and grades of scrap together with a percentage of pig-iron, is charged into the furnace and from this material heats of high-grade nickel, chrome-nickel, chrome-vanadium, high-silicon and high-manganese, high-carbon and high-speed steels may be made within a period of four to five hours, with an energy consumption of from 500 to 600 kw.-hours per ton. Under favourable conditions many heats of steel refined to under 0.02 per cent. sulphur and phosphorus have been completed in a little over three hours with a minimum energy consumption of 460 kw.-hours per ton. In making the above grades of steel, practically 90 per cent. are to carbon specifications, requiring generally considerable recarburising of the bath as well as the addition of the necessary alloys.

The cost per ton of liquid alloy steel, refined to under 0.025 per cent. sulphur and phosphorus, produced in a 5-ton Gronwall-Dixon electric melting and refining furnace is given by the author as follows:—

	s.	d.
Electric energy 550 kw.-hrs. at 0.4d.	18	4
Electrodes, 20 lbs. at 2¼d. per lb.	4	8
Refractories	1	8
Alloys*	4	0
Slag mixture—60 lbs. lime per ton of steel; 6 lbs. fluorspar per ton of steel; 10 lbs. anthracite coal per ton steel	1	1
Scrap and iron	58	0
Skilled labour	3	0
Unskilled labour	1	3
Total	92	0

* To raise the manganese content 0.30 to 0.40 per cent. from 38 to 50 lbs. of 80 per cent. ferro-manganese are added in a 5-ton furnace, or approximately 9 lbs. per ton of steel. At 4¼d. per lb. the alloy addition cost is 3s. 2d. To bring up the silicon content in the steel to approximately 0.15 per cent., it is customary to add 6 lbs. of 50 per cent. ferro-silicon which at 1¼d. per lb. makes the cost 9d.

Conversion costs per ton on steel castings in a 5-ton Gronwall-Dixon furnace follow:—

	s.	d.
Electric energy, 500 kw.-hours at 0.4d.	16	7
Electrodes, 20 lbs. at 2¼d. lb.	4	8
Refractories	1	8
Alloys (See note at foot of previous table)	4	0
Slag material	1	1
Scrap and iron	50	0
Skilled labour	2	6
Unskilled labour for charging and handling scrap		6
Total	81	6

The furnace operates with almost an absolute neutral atmosphere. In making the usual run of steels it has proved to be unnecessary to use any deoxidising agents such as ferro-manganese or ferro-silicon except as required to meet the specifications. Owing to this neutral atmosphere it is possible to add the greater part of the required alloys either with the scrap or immediately after the charge is melted, reserving only sufficient for a final adjustment of the analysis. Investigations of alloy steels made under this practice have shown uniformity and accuracy in meeting specifications.

After the melting operation, and during the refining, the passage of the current through the molten metal creates a magnetic movement of the bath producing three distinct results.

(1) It brings the entire bath in direct contact with the refining slag, materially assisting in removal of the sulphur and phosphorus. It is therefore possible, starting with a charge averaging as high as 0.10 per cent. in sulphur and phosphorus, to reduce these elements with one slag to under 0.03 per cent. Frequently the phosphorus and sulphur have been reduced to 0.01 per cent. with an additional slag. Extensive investigations of more than 800 heats have shown a minimum of segregation even in the piped section of bottom-poured ingots.

(2) This motion of the bath brings all the charge under the direct influence of the arcs. It is therefore possible to pour all the metal, leaving the furnace clean for the succeeding heats.

(3) The magnetic action of the bath produces a distribution and amalgamation of all the added alloys. This is particularly noticeable when making final additions for the adjustment of the analysis, such as metal for recarburising, ferro-manganese, nickel, chromium, or vanadium as may be required, after which additions the furnace can be tapped within ten minutes.

Refining Cupola Metal.

Another field for this furnace is the electric refining of cupola metal. Some of the results have been most encouraging. In one case fluid metal was taken from the cupola and refined in the electric furnace, the final analysis of the iron being as follows:—Silicon, 1.980 per cent.; phosphorus, 0.313 per cent.; sulphur, 0.044 per cent.; manganese, 0.73 per cent.; combined carbon, 0.63 per cent.; total carbon, 3.28 per cent.

From the metal a test bar of 1 in. sq. section was cast, the physical test being as follows:—The bar was supported on knife edges 12 in. apart and sustained a load, applied in the middle, of 3,050 lbs. before breaking, the deflection being 0.215 in. The tensile strength was 27,570 lbs., with a Brinell hardness of 202.

The figures above as regards output and energy consumption are based on the making of high-grade alloy steels to meet severe specifications.

MOULD FOR THE PRODUCTION OF SOUND INGOTS.—A process has recently been patented by Messrs. Armstrong, Whitworth & Company, in conjunction with Mr. Law and Mr. Sandberg, for the production of sound steel ingots or other castings. The metal in this case is maintained molten at the top of the ingot or casting by means of an electric arc of which the metal itself forms one of the electrodes. The arrangement is as follows:—At the bottom of the mould, and resting on its base, a plate of iron, steel, or other suitable metal is provided, with a tongue protruding beyond the mould to which is connected one of the electrical leads, the other lead being connected to an adjustable electrode. To prevent the escape of heat when the electric arc is in operation, a cover is provided for the mould with a hole for the electrode to pass through. When an ingot is to be cast, the contact plate is placed on the base, the mould is placed in position and the metal is poured into the mould. As soon as possible after the mould is filled, the cover and the electrode are lowered into position over the top of the ingot and the current is switched on. The current passes on the one hand through the baseplate, and through the metal of the ingot, which by partial welding is maintained in good contact with the plate, and on the other hand the current passes through the other lead and the electrode, and thus an arc is formed between the molten metal at the top of the mould and the electrode. The heat produced maintains the metal at the top of the ingot fluid until the rest of the ingot has solidified, and thus prevents the formation of piping, blow-holes or segregation. When the ingot has cooled, the tongue is knocked off, while the baseplate, which is now firmly welded to the ingot and forms part of it, is removed with the crop end from the bottom of the ingot.

Non-Ferrous Notes.

Rammed-in Lining for Brass-melting Furnaces.—For rammed-in linings for brass-melting furnaces in which the melting takes place without the use of crucibles, the following mixture has been recommended :—Carborundum fire sand, 70 parts ; ground fireclay, 15 parts ; silicate of soda, 8 parts ; water, 7 parts.

Cleaning Brass Castings.—A common method of cleaning brass castings after they have been taken from the mould and the gates and runners removed is to plunge them while hot into cold water and then remove the remaining sand with a steel wire brush. To brighten them, they are dipped into a mixture of equal parts of oil of vitriol and aqua-fortis, after which they should be thoroughly rinsed in running water.

Resistance-wire Alloy.—An alloy for resistance wire patented by J. T. H. Dempster (General Electric Company, U.S.A.) consists of :—Iron, 75 per cent. ; nickel, 20 per cent. ; chromium, 3 per cent. ; manganese, 2 per cent. These proportions may be somewhat varied to suit different cases. It is stated that the resistance to electric current is twice that of German-silver with a much less cost, while also the alloy has a high melting point.

Antimony in Brass.—Antimony can be used to some extent to replace tin in composition brass, though it is not advisable to entirely replace tin with it. The following mixture has been used for casting the hooks used for holding telephone receivers :—Copper, 88 per cent. ; zinc, 5.50 per cent. ; tin, 2.75 per cent. ; lead, 2.25 per cent. ; antimony, 1.50 per cent. This mixture is fairly strong, and if the castings are not such as require strength, more antimony than above given may be used, the tin being reduced accordingly.

Nickel in Brass.—Questions are often asked as to the effect of small quantities of nickel in brass mixtures—quantities such as are introduced with scrap that has been nickel-plated. The only effect is to slightly harden the metal, and as the amount so introduced is very small the effect is not injurious. The hardness is not practically noticeable until several percentage of nickel is present. The alloys of copper and zinc, with a high percentage of nickel, of course, are well known under the name of German silver, or nickel silver.

Liege Metal.—This is the name of an alloy produced in France a few years ago and used in the construction of airships. From the analysis the metal would appear to be practically a commercial magnesium. It was said to be 40 per cent. lighter than aluminium and with a density of 1.762 ; of greyish-white colour, and of the following composition :—Aluminium, 0.04 per cent. ; iron, 0.01 per cent. ; zinc, 0.44 per cent. ; sodium, 0.21 per cent. ; magnesium, 99.3 per cent. The high magnesium content, even if the alloy were specially compounded to give the composition named, discounts its value except for very special applications.

Aluminium - Copper - Tin Alloys. — Mr. E. A. Barnes, in a Paper before the American Foundrymen's Association, said : A problem with which we have had to contend is the making of aluminium castings, which would take a high polish. We tried all the standard alloys, but the castings invariably were full of small black specks due to gas in the metal. We were absolutely unable to get a satisfactory casting until we added from 8 per cent. to 10 per cent. of tin. In making this aluminium-copper-tin alloy, we found it necessary to make up a rich alloy, cast it into bars, and add this alloy to the aluminium at the proper time. The use of these eutectic alloys we have found very effective in securing results otherwise difficult to obtain.

Gas Absorption by Metals.—In the course of experiments on this subject by Sieverts and Krumbhaar, the volume of gas absorbed by a number of metals and alloys when heated to various temperatures was determined and under pressure. It was found that nitrogen was not soluble in cadmium at 400 deg. C. or in thallium, zinc, lead or bismuth at 600 deg. C., or in tin and antimony at 800 deg. C., or in silver and gold at 1,300 deg. C., or in copper, nickel and palladium at 1,400 deg. C. Aluminium absorbed nitrogen at about 800 deg. C., while iron absorbed it at about 1,200 deg. C. and did not expel it again in a vacuum, indicating the probable formation of a nitride. In the case of carbon monoxide, copper did not absorb it or react with it at 1,520 deg. C., but both solid and molten nickel absorbed it and failed to give it out again in a vacuum. Copper absorbed sulphur dioxide while molten and retained 80 per cent. when solidified, all of which was evolved in a vacuum. Hydrogen was not absorbed by cadmium, thallium, zinc, lead, bismuth, tin, antimony, silver or gold. Copper, nickel, iron and palladium absorbed hydrogen. On cooling, copper retained 20 per cent. and nickel 8 per cent. of the hydrogen absorbed, while in the case of iron the evolution of the gas in the vacuum was very violent.

Making Chromium-Bronze.—The following are the details of a simple method of making chromium-bronze which was developed in Germany :—Chromium chloride is heated with metallic zinc and the chromium is reduced to metal which alloys with the zinc, while zinc chloride is obtained at the same time. Alloying the zinc with 2 per cent. of aluminium was said to make the reaction take place more rapidly. To make the bronze mixture the alloy of zinc and chromium produced is added to copper. To produce 100 lbs. of chromium-bronze, 3.2 lbs. of chromium chloride are heated with 40 lbs. of zinc. The alloy of zinc and chromium obtained is added to 57 lbs. of copper. This quantity will give a bronze containing about 1.25 per cent. of chromium in the alloy. To produce a bronze containing a desired amount of chromium, it was stated to be necessary to take two and one-half times as much chromium chloride as the quantity of chromium desired. The composition of one chromium-bronze made by this process was given as copper 58 per cent., zinc 41 per cent., chromium 1 per cent. The physical properties were stated as :—Tensile strength, 82,000 lbs. per sq. in. ; elastic limit, 41,000 lbs. per sq. in. ; elongation, 18 to 20 per cent. A manganese-bronze may be made by the same method, except that manganese chloride is used instead of chromium chloride. To introduce 1 per cent. of manganese in the bronze, it is necessary to use 3.2 lbs. of manganese chloride when 100 lbs. of bronze are to be made.

Tantalum.—This rare metallic element (Symbol Ta) has a specific gravity of 16.64, and atomic weight 181.5. It is iron-grey in colour, capable of taking a good polish and sufficiently hard to scratch glass or quartz. Its ductility and tenacity are very great. It is sometimes employed alone or alloyed with iron and other metals in the manufacture of drills, files, cutting edges and other tools and parts of mechanism. Tantalum is insoluble in the common mineral acids, including aqua-regia ; but concentrated sulphuric acid dissolves it very slowly, and it is also dissolved by fused alkalis. Water is without action on it at 600 deg., while its melting point is 2,250 to 2,300 deg. C. The metal has been prepared by reduction of potassium-fluoro-tantalate (K_2TaF_7) by hyrogen, followed by fusion in a vacuum. Another method consists in reducing the pentoxide with excess of aluminium and removing the latter by heating with the arc in a vacuum. In a process of making malleable and ductile tantalum developed by M. Von Pirani for Siemens & Halske, Germany, tantalum hydride was produced by heating tantalum chloride in hydrogen. When tantalum hydride is heated in the air, it oxidises, and if heated strongly in an atmosphere of hydrogen, the greater part of the hydrogen gas is given off and re-absorbed again upon cooling. The tantalum hydride is brittle, and in order to obtain the ductile tantalum the tantalum hydride is heated in a vacuum by means of an electric current so that it is actually raised to a white heat or above its melting point. The vacuum is maintained during the heating so that all gas that is expelled is removed. Tantalum readily absorbs nitrogen, hydrogen or oxygen, so that it cannot be produced in the atmosphere.

Trade Talk.

THE Swedish Government has prohibited the export of screws of copper or copper alloys.

ROBERT WARNER & COMPANY (ENGINEERS), LIMITED, are transferring their London business to Walton-on-Naze.

MESSRS. E. GRIFFIN & COMPANY, engineers' merchants, etc., have removed to 12, Railway Approach, London Bridge, S.E.

AT a meeting of the Manchester Association of Engineers on December 9, Mr. J. Edgar Hurst read a paper on "Cast Iron."

CONSIDERABLE damage was done by a fire which broke out last month in the premises of Messrs. James Lamont & Company, ship repairers, Greenock.

MESSRS. GEO. ROBSON & COMPANY have removed from Napier Street, Sheffield, to the Eclipse Engineering Works, Hodgson Street, Sheffield.

PLANS were presented to the Little Hulton (near Bolton) District Council, last month, by E. Bennis & Company, Limited, for extensions to their works.

THE directors of the Millom and Askam Hematite Iron Company, Limited, have decided to subscribe £1,000 to the Kitchener Memorial Fund.

MESSRS. H. HOLMES, A. HOLMES, and H. MIDGLEY, machine tool makers, Central Ironworks, Halifax, trading as Henry Holmes & Company, have dissolved partnership.

MESSRS. F. O. RUSSELL and G. H. PEARSON, metal-workers and brass-founders, 25½, Price Street, Birmingham, trading as F. O. Russell & Company, have dissolved partnership.

MESSRS. J. D. WHITWORTH, T. A. WHITWORTH and J. DAVIES, fire engineers, brass founders and coppersmiths, 203, Chapel Street, Salford, Manchester, trading as Robert Watkinson, have dissolved partnership.

THE recent proposal that was made to the Government on the subject of the establishment of a Central Department of Minerals and Metals is, we understand, receiving sympathetic consideration.

THE BRITISH ROPEWAY ENGINEERING COMPANY, LIMITED, 34, Fenchurch Street, London, E.C., have recently purchased from the Controller for the Board of Trade the enemy business known as Bleichert's Aerial Transporters, Limited.

AN explosion occurred on December 18 at the metal refinery of Messrs. H. B. Barnard & Sons, Vauxhall, London, S.E., resulting in the death of one man and injuries to another. An outbreak of fire followed, but was quickly subdued, the damage to the works being slight.

THE difficulties of obtaining adequate supplies of raw material for the manufacture of lead products has caused Walkers, Parker & Company, Limited, to enter into friendly co-operation with H. J. Enthoven & Sons, Limited, importers, smelters, and refiners.

THE partnership heretofore subsisting between Messrs. W. Walker and J. Larking, carrying on business as engineers, brass founders, and metal merchants, at Liverpool, under the style of A. & R. Brown & Company, has been dissolved.

S. F. & S. P. T., LIMITED, is the title of the company formed by the recent amalgamation of Samuel Fox & Company, Limited, and Steel, Peech & Tozer, Limited. Full details are published elsewhere in this issue. Presumably it is a "holding" company only.

AT the meeting of the Staffordshire Iron and Steel Institute, at Dudley, last month, Professor H. C. Carpenter read a paper giving typical cases in which difficulties arose owing to the welding or distortion of cast-iron which is rapidly heated or heated for a long period, and indicating some remedies.

THE MINISTER OF MUNITIONS announces that he has made further Orders under the Munitions of War Acts, 1915 and 1916, under which additional establishments have been declared controlled establishments. The total number of controlled establishments under the Munitions of War Acts, 1915, and 1916, is now 4,585.

AN order has been made by the Board of Trade requiring the under-mentioned business to be wound up:—Vintit Company, Limited, Apollo Works, 21, South Road, New Southgate, London N., agents for the sale of carborundum and electrite machinery. Controller: C Eves, Capel House, 62, New Broad Street, London, E.C. November 29, 1916.

A PROCLAMATION has been issued deleting the following headings from the list of prohibited exports:—Metals and ores, the following—(B) scheelite; (B) wolframite. The following headings have been added:—Metals and ores, the following—(B) tungsten ores (including ferberite, hubnerite, scheelite and wolframite).

THE BLYTH SHIPBUILDING AND DRY DOCKS COMPANY, LIMITED, have purchased a piece of land containing 25,500 square yards. The directors have not as yet decided whether it should be used to extend the shipyard or for the making of a repairing establishment. If it is used to extend the shipyard it will give the company three additional berths of large size. At present the company have 47,105 square yards in use.

THE PRIORITY BRANCH OF THE MINISTRY OF MUNITIONS has moved to its new premises in a wing of St. Ermins Hotel. The official address will be known as 1, Caxton Street, Westminster, S.W. Mr. Edgar Jones, M.P., who is head of this branch of the Ministry, will have charge of machinery for controlling the use and distribution of metals under the new committees that have been recently appointed for effecting economies in metals.

AT a meeting at Swansea last month to promote the claims of the Swansea Technical College to be raised to University status, the Mayor announced subscriptions to the endowment fund amounting to £71,000. This sum includes £10,000 each from Baldwins, Limited, and the South Wales Siemens Steel Association, and £5,000 from the Briton Ferry Steel Company, Limited.

IT is announced that David and William Henderson & Company, Limited, Meadowside Shipyard, Glasgow, have acquired an interest in the business of A. & J. Inglis, Limited, who occupy the adjoining yard at Pointhouse. There will be no change in the management of the two concerns, Dr. Inglis remaining chairman and his sons directors of A. & J. Inglis, Limited, and Mr. Fred N. Henderson will be the chairman and managing director of David and Wm. Henderson & Company, Limited.

A PROCLAMATION has been issued adding the following to the list of prohibited exports:—Metals and ores: (c) Iridium, osmium, palladium, rhodium, ruthenium and alloys of these metals; (b) lead (except in pig lead), alloys of lead, solder containing lead, and manufactures of lead or its alloys, not otherwise prohibited; (a) thorium and its alloys; (a) zirconium and its alloys; (a) fuel economies constructed of cast-iron pipes, used as auxiliary heating apparatus in connection with land or marine steam boilers.

A MEETING has been held at Manchester of manufacturers of refractory materials to consider the proposed formation of an association to represent the interests of the trade, which should become a section of the English Ceramic Society. Dr. J. W. Mellor, in reviewing the situation, remarked that 59 firms had promised their support, the majority of whom were represented at the meeting. After considerable discussion, a provisional committee was elected, and secretaries appointed to represent the Society in Scotland, Yorkshire, Wales, and other manufacturing areas.

ON Friday, December 8, the Minister of Munitions issued an order prohibiting the use of copper, whether wrought or unwrought, in any kind of manufacture, except for the purposes of a contract or order for the time being in existence certified to be within Classes "A" or "B" of circular L.33 as to control of output issued by the Minister of Munitions on March 31, 1916. The order of the Minister of Munitions of November 6 1916, relating to the manufacture of copper wire and cable containing copper is cancelled. All applications in reference to this order should be addressed to the Ministry of Munitions of War, Priority Branch, 1, Caxton Street, Westminster, London, S.W.

Deaths.

Mr. Alexander Dimmack, iron merchant, Giffnock, died on the 11th ult.

Mr. Arthur Wilson, manager of a machine shop at the works of Wm. Jessop & Sons, Limited, Sheffield, died suddenly last month.

The death took place on December 14 of Mr. E. G. Needham, chairman of Needham Bros., Limited, Matilda Street, Sheffield, at the age of 42 years.

Emeritus-Professor Thomas Purdie, of the Chemistry Chair, St. Andrews University, died at his residence on December 14, at the age of 73 years.

The death is announced from the United States of Mr. W. W. Scranton, of Scranton, Pa., at one time a leading manufacturer of Bessemer steel, aged 72 years.

The death occurred on December 9, at Spencer Street, Carlisle, after a very short illness, of Mr. John Pratchitt, head of the well-known engineering firm of Pratchitt Bros., Carlisle.

The death has occurred at his residence, Wharfe View Terrace, Otley, at the age of 71 years, of Mr. E. Crossfield, chairman of the firm of Fieldhouse, Crossfield & Co., Limited, engineers.

Mr. William Macmillan, who died in Glasgow last month, aged eighty years, was for forty-six years a partner in the firm of Messrs. A. & J. Inglis, engineers and shipbuilders, Glasgow.

Mr. W. H. Gibson, of Sowerby Bridge, who has died at the age of 65 years, was for 47 years connected with the firm of Messrs. Pollit & Wigzell, engineers, Sowerby Bridge, latterly as secretary and director. He retired in 1913.

Capt. Douglas Stuart Phorson, Durham L.I., who has been killed in action, was the eldest son of Mr. P. Phorson, Roker Park Road, Sunderland, works manager and a director of J. L. Thompson & Sons, Limited, shipbuilders.

The death has taken place at North Scarle, near Lincoln, of Mr. Charles Duckering. He was for many years head of the Waterside Foundry, Lincoln. Mr. Duckering was in his seventy-sixth year, and retired from the business a few years back.

The death is reported of Dr. Wilhelm Merton, of Frankfort-on-the-Main, at the age of 68 years. He organised the well-known Metall-Gesellschaft, the Australian branches of which have been wound up through the patriotic action of Mr. Hughes.

The death is reported of Mr. W. H. Bale, of Drakefell Lodge, St. Catherine's Park, London, S.E., at the age of 73 years. The deceased was well known as a consulting engineer, and at the time of his death was senior partner of Messrs. Bale & Hardy, Queen Victoria Street, E.C.

Captain Reginald Noel Davis, Duke of Wellington's Regiment, who has been killed in action, was a son of the late Mr. F. B. Davis, of Newcastle-on-Tyne. The deceased officer was born in 1890, and was educated at Christ's Hospital from 1899 to 1906. Up to 1914 he was connected with the Northumberland Shipbuilding Company, Limited.

The death occurred on December 12, at his residence, Palm House, Foundry Vale, Waterfoot, of Mr. Walter Haworth, aged 50 years, who was a member of the firm of John Haworth & Sons, Bridge End Foundry, Waterfoot, Rossendale, Lancs. He was a son of Mr. Emanuel Haworth, of the same firm, and was well known in northern engineering and foundry circles.

The death has taken place at his residence, 7, Greenfield Terrace, Gosforth, of Mr. Thomas Walton. The deceased was born in 1826, and was engaged in lead mining in that neighbourhood from a very early age. He went to Messrs. Locke, Blackett & Company, lead manufacturers, Newcastle, many years ago, and for a long while was their representative on the Quay, retiring in 1895.

The death has taken place at his residence, 15, Rowlandson Terrace, Sunderland, of Mr. James Brotherton, outside manager for the North-Eastern Marine Engineering Company at the firm's Sunderland works. Mr. Brotherton, who was a native of Cessford, Roxburghshire, was born in 1858. He was well known in shipping and engineering circles throughout the North and was highly respected by all who knew him.

We regret to announce the death of Mr. M. B. Baird, of the firm of Messrs. Archibald Baird & Son, Clyde Steel and Engineering Works, Hamilton. Mr. Baird, who was seventy-one years of age, was connected all his life with the iron and steel industry, and was well known also to the business community through his association with the Trades House and the Merchants' House. Mr. Baird was a member of the Iron and Steel Institute and of the Institution of Mining Engineers.

Mr. Robert Colver, of the firm of Jonas & Colver, Limited, Continental Steel Works, Sheffield, and a past Master Cutler, died at his residence, Rockmount, Ranmoor, on December 2, at the age of 74 years. Mr. Colver originally devoted his attention to agriculture, but had been associated with the steel trade for many years, and had helped materially in the vast expansion of the firm, which commenced in 1873. He was also a director of J. & G. Wells, Limited, of the Eckington Colliery. He was Master Cutler in 1890.

We regret to announce the death of Mr. Archibald Colville, of Arngomery, Stirlingshire, which occurred at the Mooring, Motherwell, on December 11, in his 64th year. The deceased gentleman was chairman of David Colville & Sons, Limited, of Dalzell Steel and Iron Works, Motherwell. He was a native of Glasgow, and when 17 began his business career with Messrs. James Finlay & Company, East India merchants, Glasgow. He, however, joined his father at Motherwell when the latter started the Dalzell Iron Works, and for almost 45 years he was associated with the commercial side of the Dalzell establishment.

We regret to record the death of Sir Hiram Maxim, which took place on November 24, at his residence in Streatham. He was probably one of the greatest inventors of modern times. Sir Hiram was of American birth, but he had for many years been naturalised in this country. Born in February, 1840, in Maine, U.S.A., he was educated as a civil engineer, in which profession his remarkable talents soon secured him eminence. His fame will always be associated with the quick-firing machine-gun which bears his name and which he invented and perfected after long years of experiments. But hardly second to this epoch-making revolution in warfare was his work in connection with aerial navigation, and there is no doubt that his experiments and inventions in respect of this new science materially assisted to bring it to the advanced stage at which it stands to-day. In fact, the name of his inventions was legion. They included automatic gas machines and engines of destruction. He was the first to combine nitro-glycerine and gun-cotton in a smokeless powder, the first to design and patent a delayed action fuse, and among the first to work out the possibilities of electricity for lighting and other purposes. In 1877 he was retained as consulting engineer to a Mr. Schuyler, who was engaged in the development of electtic lighting in the United States. The earliest electric lights in the States were devised and erected by Mr. Maxim, who also invented several important improvements in electrical apparatus. In 1881 he became permanent representative in Europe of the American company with which he was connected. In 1883 he came to England, and made London the headquarters of the European business of the company. When he came to England with his automatic gun he was fortunate in meeting Mr. Albert Vickers, of the Vickers firm, with whose co-operation the Maxim-Nordenfeldt Company was formed. The companies were later amalgamated as Vickers, Sons and Maxim, Limited, now Vickers, Limited. Sir Hiram retired from the company some years ago.

Personal.

THE late Mr. F. Jevons, of Messrs. Jevons & Company, iron merchants, Liverpool, left £31,384.

THE late Mr. W. McNaught, of John & William McNaught, engineers, Rochdale, left estate valued at £143,223 gross.

LIEUT. F. GEORGE, son of Mr. E. J. George, secretary to the Consett Iron Company, Limited, has been severely wounded.

THE HON. SIR JOSIAH SYMON, K.C.M.G., K.C., of South Australia, has been elected a Vice-President of the Royal Colonial Institute.

THE gross value of the estate of the late Mr. W. S. Laycock, head of W. S. Laycock, Limited, and Cravens, Limited, is £71,1[illegible]8.

A PEERAGE has been conferred upon the Right Hon. Charles B. Stuart-Wortley, M.P., a director of J. Grayson, Lowood & Company, Limited.

THE gross value of the estate of the late Mr. E. C. Blackstone, of Messrs. Blackstone & Company, engineers, Stamford, Lincs., is £118,802.

MR. A. WALLACE COWAN, who is in charge of the business at Manchester of Redpath, Brown & Company, Limited, has been elected a director of the company.

THE gross value of the estate of the late Mr. J. Proctor, senior partner in Messrs. Proctor Brothers, Leeds and Bradford Wire Works, Call Lane, Leeds, is £7,410.

THE gross value of the estate of the late Mr. R. G. Walker, a member of the firm of Messrs. Walker Brothers, galvanisers, is £14,649, including net personalty of £13,343.

MR. A. GIBB, managing director of Easton, Gibb & Son, Limited, has been appointed with the rank of lieutenant-colonel to the staff of General Sir Eric Geddes, Director-General of Transport.

OWING to the death of Mr. W. Allday, the number of directors of Alldays & Onions Pneumatic Engineering Company, Limited, has been increased by the election of Mr. J. C. Vaudry, Mr. N. Tailby, and Mr. P. W. Allday.

MR. R. P. LION has been taken into partnership by Messrs. Philipp Brothers, metal, ore and mineral merchants, 133, Fenchurch Street, London, E.C., and in future the business will be carried on under the style of Philipp, Lion & Company.

SIR PERCY GIROUARD has rejoined the board of Sir W. G. Armstrong, Whitworth & Company, Limited, and Lord Sydenham, Colonel Hadcock, and Sir Phillips Watts have been elected directors, but Lord Sydenham has since had to resign.

MR. A. JOSEPH, scrap metal merchant, of Earl Street, London Road, Southwark, S.E., has offered to subscribe £500 if the members of the Metropolitan waste and scrap trades will provide another £1,500 before the end of the year, for the purpose of presenting motor ambulances to the British Red Cross Society.

THE Ministry of Munitions have appointed Mr. Cecil Budd, of Messrs. Vivian Younger & Company, London, and Mr. R. M. Rucker, of Messrs. Henry Rodgers, Sons & Company, London, as a committee to advise the Ministry on the purchase and distribution of copper. Mr. Budd is chairman of directors of the London Metal Exchange, and Mr. Rucker is chairman of the Metal Exchange. Mr. Stroud, of Messrs. Charles Tennant & Company, will act as secretary to the Committee.

MR. ARTHUR NEVILLE CHAMBERLAIN, Lord Mayor of Birmingham, who has been appointed Director of National Service, received his education at Rugby, after which he went to the West Indies as manager of an estate his father had acquired. Subsequently he became associated with Elliott's Metal Company, Limited. Later he acquired the business of Messrs. Hoskin & Son, manufacturers of metallic ships' berths, and also became a director of the Birmingham Small Arms Company, Limited.

As a result of the purchase of the Duke of Devonshire's shares in the Barrow Hematite Steel Company, Limited, by the Millom & Askam Hematite Iron Company, Limited, Mr. Mure Ritchie, chairman of the latter company, has been elected chairman of the Barrow Board, and three other members of the Millom concern will have seats on that directorate. The first chairman was the seventh Duke of Devonshire, who was followed by the Marquis of Hartington, afterwards eighth Duke, and he was succeeded by the present Duke, now Governor-General of Canada.

THE Italian bronze medal for valour has been awarded to Mr. D. L. Cooper, of Middlesbrough. When the war commenced Mr. Cooper was assistant manager for the North-Eastern Steel Company, Limited. Rejected for active service, he joined the British Red Cross Society as a voluntary motor ambulance driver, serving until the autumn of 1915 in France. When the Italian Government appealed for ambulance workers he responded to the call, and has been in the Alps since then. He has now been recalled to take the place of his brother as general manager of the steelworks. According to the official bulletin of the Italian Ministry of War, Mr. Cooper gave his services with exemplary courage, coolness and carefulness, during many days of fighting in transporting the wounded with his motor ambulance upon difficult roads, which were subject to intense bombardment by the enemy's artillery.

THE committee which was formed with the object of commemorating the late Sir William White's services to the nation in the development of engineering science, and more particularly of naval architecture, has now completed its task. A sum of £3,197 14s. 8d. was raised by private subscriptions, and this amount has been expended in the following directions: (1) The provision of a fund for providing a post-graduate research scholarship in naval architecture of over £100 per annum, tenable for two years; (2) the erection of a memorial panel; (3) the donation of 100 gs. to the Westminster Hospital. The research scholarship fund has been made over to the Council of the Institution of Naval Architects, who will administer the fund and award the scholarship. The latter is to be known as the "Sir William White Research Scholarship in Naval Architecture." The memorial panel has been erected in the entrance hall of the Institution of Civil Engineers.

Applications for Patents.

The names of communicators are printed in Italic type. A new number will be given when the Complete Specification is accepted.

Aciéries et Fonderies d'Art de Haine-St.-Pierre et Métallurgique Lilloise Soc. Anon. Ramming-devices for moulding. 17,153. November 29. (Germany, December 2, 1915.)

Bean, J. S. & J. G. Drying and screening sand, etc. 17,241. December 1.

Cockram, T. R. J. Apparatus for casting ingot moulds. 17,396. December 4.

Electro Metals Products Company. Alloy. 17,569. December 8. (United States, September 29.)

Gray, R. Steel-making, etc., furnaces or mixers. 17,147. November 29.

Grocott, F. J. Furnace for annealing, case-hardening, fusing, etc. 17,554. December 7.

Hall, I. Means for casting. 16,961. November 27.

Lowe, J. R., and Wragg, J. H. Ingot, etc., moulds. 17,744. December 9.

Sandberg, C. P. Method for hardening surface of steel articles. 17,123. November 29.

Soc. C. M. Stein et Cie. Crucible smelting-furnaces. 16,891. November 24. (France, August 29.)

Soc. C. M. Stein et Cie. Furnaces. 16,895. November 24. (France, May 25.)

Soc. C. M. Stein et Cie. Rocking-devices for mixers. 16,939. November 25. (France, October 23.)

Southall, J. Making sand moulds for casting metal castings. 16,777. November 23.

Thornycroft & Company, J. I. Furnace fronts for liquid-fuel furnaces. 16,723. November 22.

Wellman, Seaver, & Head. Steel-making, etc., furnaces or mixers. 17,147. November 29.

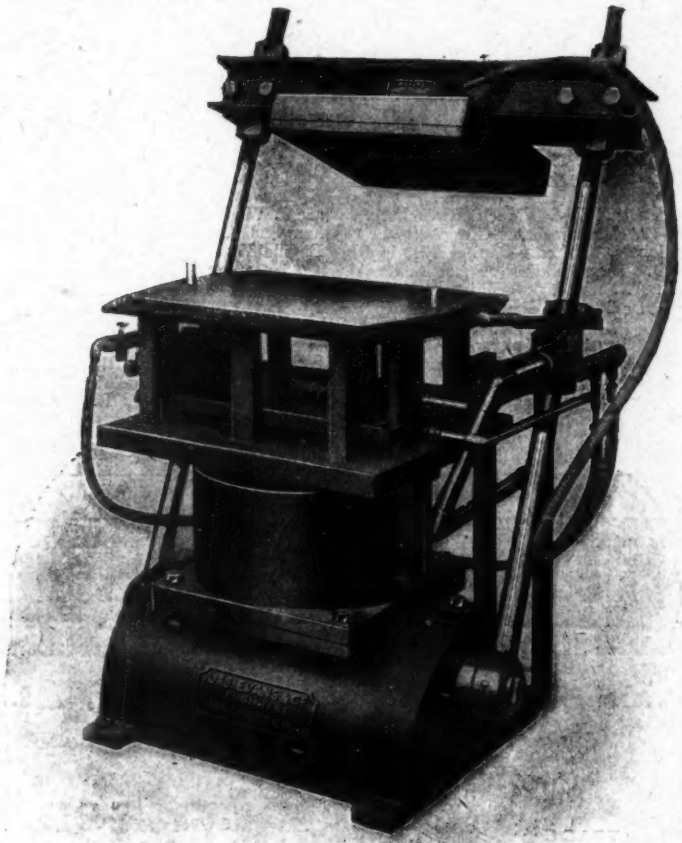
Wilson, G. A. Manufacture of steel ingots. 17,119. November 29.

Yates, H. J. Furnaces. 16,662. November 21.

MOULDING MACHINES

OF EVERY DESCRIPTION.

Pneumatic, Hydraulic, Jar Ramming, & Hand Power.



JAMES EVANS & CO., BRITANNIA WORKS,

BLACKFRIARS, **MANCHESTER.**

New Companies.

Brydon & Company, Limited.—Capital £10,000 in £1 shares, to carry on the business of engineers, etc.

S. Y. S. Engineering Company, Limited. — Capital £1,200 in £1 shares, 600 6 per cent. cumulative preference.

Davie Brothers, Limited. — Capital £2,000 in £1 shares, to acquire the existing business of engineers, etc. Registered office: 436, Argyle Street, Glasgow.

Lane's, Limited.—Capital £5,000 in £1 shares, to carry on the business of lead manufacturers. Registered office:—45a, New Church Street, Bermondsey, S.E.

E. T. Neal & Company, Limited.—Capital £4,000 in £1 shares, to carry on the business of engineers, founders, etc. The first directors are E. T. Neal and J. S. Burton.

British Compressed Air Pumps Limited.—Capital £2,500 in 2,000 ordinary shares of £1 each, and 10,000 deferred shares of 1s. each. The first directors are E. A. Eenever and F. H. Bailey.

A. Jackaman & Son, Limited.—Capital £50,000 in £1 shares (25,000 5 per cent. cumulative preference), to carry on the business of engineers, etc. Registered office:—22, Mackenzie Street, Slough.

Ben Nevis Engineering Company, Limited.—Capital £2,000 in £1 shares, to acquire the business at present carried on by the Ben Nevis Machine Company. Registered office:—10, Renfrew Lane, Glasgow.

West Riding Engineers, Limited.—Capital £500 in £1 shares (100 deferred). The first directors are A. Crowther, S. Parsons, B. A. Pickles, J. Wilkinson, and W. Armitage. Registered office: 21, Prudential Buildings, Ivegate, Bradford.

Woodward, Gatty, Saunt, & Company, Limited.—Capital £21,000 in 20,000 ordinary shares of £1 and 20,000 deferred shares of 1s., to carry on the business of ironfounders, etc. Registered office:—Caxton House, Westminster, S.W.

Rapid Steel Company, Limited.—Capital £2,000 in £1 shares, to take over the business carried on at 66, Mount-Pleasant, Liverpool, as the Rapid Steel Company. B. S. Bernstein is permanent managing director. Registered office: 66, Mount Pleasant, Liverpool.

T. W. Pearson, Limited.—Capital £3,000 in £1 shares, to adopt an agreement with A. E. Pearson, trading as T. W. Pearson at Leadmill Street, Sheffield, and to carry on the business of manufacturers, melters and rollers of or dealers in steel, etc. A. E. Pearson is permanent governing director.

Wight & Company, Limited.—Capital £10,000 in £1 shares, to carry on in the United Kingdom or elsewhere the business of metal brokers and merchants, etc., and to acquire the business carried on at Sunderland as Wight & Company. The first directors are G. O. Wight (chairman), J. F. Potts, and O. S. Wight.

Anchor Metal Works, Limited.—Capital £500 in £1 ordinary shares. Directors to be appointed by the subscribers. Subscribers (one share each):—E. R. Birkley, 63, Temple Row, Birmingham, solicitor; T. W. Robinson, 63, Temple Row, Birmingham, solicitor. Registered office: Anchor Metal Works, Beckly Street, Birmingham.

John Wigham & Sons, Limited.—Capital £25,000 in £1 shares (5,000 preference) to take over the business of engineers, ironfounders and ship-repairers formerly carried on by J. Wigham and J. R. Wigham at South Hylton as John Wigham & Son. The first directors are J. Wigham (chairman), J. R. Wigham, J. T. Wigham and S. Wigham. Registered office:—South Hylton Engine Works, South Hylton, near Sunderland.

The Tyne Electric Steel Foundries, Limited.—Capital £39,750 in 35,000 preference shares of £1 each and 95,000 ordinary shares of 1s. each, to take over the business of the Electro Flex Steel Company, Limited (incorporated in 1911), etc., and to adopt an agreement between W. Swan and R. P. Sloan. The first directors are: F. S. Newall, R. P. Sloan, W. H. McAlpine, A. D. C. Parsons, and R. E. E. Spencer. Registered office: Dunston-on-Tyne.

WE MANUFACTURE FANS FOR EVERY PURPOSE FOR WHICH A FAN CAN BE USED. HIGH PRESSURE FANS FOR BLOWING CUPOLAS AND FORGE FIRES. VOLUMETRIC FANS FOR VENTILATION. INDUCED DRAFT. &c.. &c.

FANS

Davidson & Co., Limited,

Sirocco Engineering Works,

BELFAST.

LONDON. MANCHESTER.
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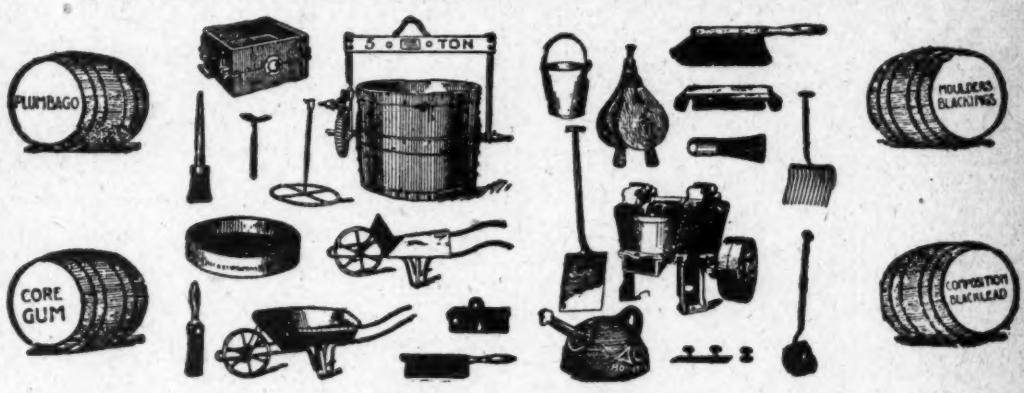
Telegrams: "Durrans, Penistone." Telephone: 21, Penistone

Established 1863.

JAS. DURRANS & SONS,

Phœnix Works, Penistone, Near Sheffield.



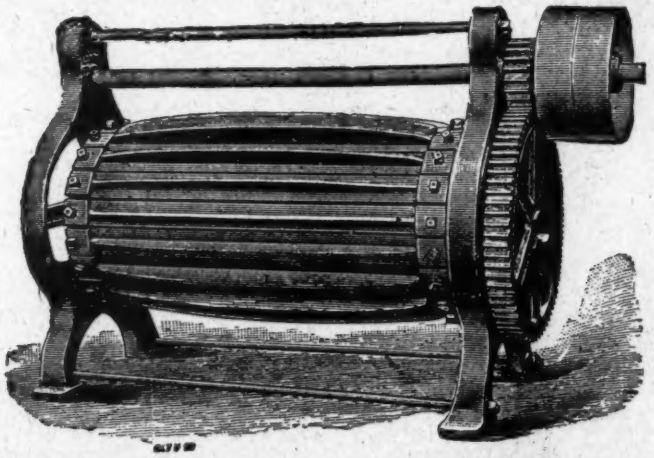
Manufacturers of all

FOUNDRY EQUIPMENTS

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

Improved Foundry Rattler or Fettling Drum.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

The following testimonial explains itself :—

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD.

MONTHLY PRICE LIST.

The undermentioned prices, unless otherwise specified, are those obtaining at the commencement of the current month.

CONTROL PRICES.

These maximum prices of iron, steel and coke were fixed by the Government until June 30, 1916, and thereafter until further notice. Makers may sell for delivery after June 30, on the understanding that the fixed maximum prices ruling on the 1st day of any month during the period of the contract will apply to all deliveries made during that month. This intimation must not be taken to authorise any sale or purchase or other dealing prohibited under the Defence of the Realm Regulations

Pig-Iron.

	£	s.	d.
West Coast hematite, mixed Nos., 1, 2 and 3	6	7	6
Special under 0.03 P. & S... ..	6	15	6
„ „ 0.02 „	7	0	0
East Coast hematite, mixed Nos. 1, 2 and 3	6	2	6
Special under 0.04 P. & S. ..	6	7	6
Special under 0.03 P & S. ..	6	15	6
„ „ 0.02 „	7	0	0
Scotch hematite, mixed Nos. 1, 2 and 3..	6	2	6
Special under 0.03 P. & S. ..	7	10	0
Welsh hematite, mixed Nos. 1, 2 and 3	6	2	6
Special under 0.03 P. & S. ..	6	15	6
„ „ 0.02 „	7	0	0
Lincolnshire, basic or foundry ..	4	12	6
Cleveland, No. 1	4	11	6
„ other grades	4	7	6
Northamptonshire, forge	4	7	6
„ fdy numbers	89/0		94/0
Derbyshire, forge	4	10	0
„ foundry numbers	92/6		96/6
Derby & Notts. basic.	4	17	6
Leicestershire & Notts., forge ..	4	10	0
„ „ foundry nos.	92/6		96/6
North Staffs, forge	4	15	0
„ „ foundry	4	17	6
„ „ basic	4	17	6
South Staffordshire—			
Part mine forge	4	15	0
„ foundry	4	17	6
Common Staffordshire	4	10	0
All mine forge	5	15	0
„ foundry	6	0	0
Warm air forge	7	5	0
„ foundry	7	15	0
Lord Dudley's silicon	8	7	6
Cold blast	9	2	6
Scotch foundry and forge—			
Nos. 3, 4, and lower grades of Monkland, Dalmellington, Eglinton, and Govan.. ..	5	14	0
Nos. 3, 4, and lower grades of all other brands	5	15	6

No. 1 quality in all cases to be 5s. per ton above these prices.

All per ton net, f.o.t. makers' works. Mers. Com. 1½%

High-Speed Tool Steel.

The maximum prices for high-speed tool steel have been fixed as follows:—

Finished bars, 14% Tung. 2s. 10d.

Finished bars, 18% Tung. 3s. 10d.

Per lb. basis. Extras as per authorised list. These prices are net delivered buyers' works.

The fixed prices for scrap which must be returned to steel makers' works are as follows:—

Millings and Turnings	5d
Bar Ends	6d

Both per lb. net delivered steel makers works.

Ferro-Alloys

Net, Delivered Sheffield steel works.

	£	s.	d.
Ferro chrome: 4/6% carbon. Basis 60%, scale 10s. per unit Per ton	—		
Ferro-chrome: 6/8% carbon. Basis 60%, scale 10s. per unit. Per ton	—		
Ferro-chrome: 8/10% carbon. Basis 60% scale, 10s. per unit Per ton	—		
Ferro-chrome: Specially refined, guaranteed maximum 2% carbon broken to small pieces for use in best quality crucible steels. Basis 60%, scale 32s. per unit. Per ton	—		
Ferro-vanadium: 33/40% Va., per lb. of Va. contained in the alloy	—		
Ferro-silicon: 45/50%. Basis 50%. 5s. scale per unit .. Per ton	—		
Ferro-titanium: 23/25%, per lb. carbonless..	—		
Ferro-molybdenum: 70/80% Mo. per pound of Mo. contained ..	—		
Ferro-phosphorus: 20/25%. Per ton	—		
Ferro-tungsten: 75% to 80% per lb. of metallic tungsten contained	—		
*Ferro-manganese 80%	—		
„ export	—		

* F.o.b. Liverpool.

Non-Ferrous Metals.

Copper.

	£	s.	d.	£	s.	d.
Standard, Cash	133	0	0	133	10	0
Three months	129	0	0	129	10	0
Electrolytic	144	0	0	141	0	0
Tough	—			—		
Best selected	—			—		

Tin.

	£	s.	d.	£	s.	d.
Standard, Cash	180	15	0	181	0	0
„ Three months	182	10	0	182	15	0
English Ingots	—			183	0	0
Bars	—			—		
Refined	—			—		

Spelter.

American	—			50	10	0
Specials	—			—		
Hard	—			—		
British	—			—		

Lead.

Soft Foreign	—			30	10	0
English	—			32	5	0

Antimony.

Regulus	—			—		

Aluminium.

Virgin Metal 98/99% per ton	—

Phosphor Bronze.

INGOTS.	Per ton.
Alloy No. I. or II	—
III., IV. or V.	—
VI. or VII.	—
VIII.	—
XI.	—
Cast Strips and Ingots	—

CASTINGS.	Per lb.
I. or II.	—
III. IV. or V.	—
VI. or VII	—
VIII.	—
XI.	—
No. VII., Chill, Cast, Solid	—
„ Cored Bars	—

Delivery 2 Cwt. free to any town.

10 per cent. Phosphor Copper .. 35/- above price of best selected copper.

15 per cent. Phosphor Copper .. 40/- above price B.S.

Phosphor Tin (5 per cent.) .. £23 above price of English Ingots.

(Phosphor-bronze prices supplied by CHARLES CLIFFORD AND SON, LIMITED, FAZELEY STREET MILLS, BIRMINGHAM).

***Chromium (Metallic).**

98/99% purity, per lb.	—

***Nickel.**

In cubes, 98/99% purity Per ton	—

Nickel Silver.

	per lb.
Ingots for raising	—
Ingots for Spoons and Forks ..	—
„ rolled to spoon size ..	—

***Tungsten Metal Powder.**

96/98% purity.. per lb. ..	—

***Molybdenum Metal.**

96/98% purity.. per lb. ..	—

***Cobalt Metal.**

97% purity .. per lb. ..	—

Quicksilver.

75 lb. bottle	—

* Net, Delivered Sheffield Works.

Scrap Iron and Steel.

Cleveland.

	s.	d.	s.	d.
Steel scrap, heavy melting..	110	0	—	
Iron scrap cast (cupola metal)	80	0	85	0

London (f.o.b.).

Heavy steel	85	0	
Light „	45	0	
Heavy cast	80	0	

Control Prices.

Heavy Steel Melting Scrap	105	0	125	0
Turnings and Borings			50	0

Per ton delivered Buyers' Works.

Non-Ferrous Scrap.

London merchants quote the following prices for scrap metal, delivered London, and subject to market fluctuations:—

	A. Joseph. £	s.	d.
Hy. Electrolytic Copper Scrap ..	—		
Hy. Selected Scrap Brass ..	—		
Hy. Tinned Copper Wire	—		
Best Selected Gunmetal Scrap ..	—		

Re-melted Ingot Lead — under English Lead price on date of order.

Stocks.

Metals.	Tons.
Copper, Europe and afloat	—
Tin, London, Holland, U.S.A. and afloat	21,085

Coke.

Middlesbrough.

	s.	d.	s.	d.
Gas Coke	32	6	—	

Glasgow.

Foundry Coke	—		42	6
Furnace Coke	31	0	—	
Gas Coke	—			

London.

Welsh or Durham Foundry, d/d London Stations in truck	45	6	53	0
Ditto, d/d Birmingham Stations	44	0	48	0
Yorkshire, d/d London Stations, in truck	42	6	—	
Ditto, d/d Birmingham Stations	39	6	—	

CONTROL PRICES OF COKE.

	s.	d.
Durham and Northumberland blast furnace	28	0
„ foundry	30	6
South Yorkshire, West Yorkshire, Lancashire, Staffordshire and Midland Counties blast furnace	25	8
South Wales blast furnace ..	30	0
„ foundry	43	0

All per ton net. f.o.t. ovens.

SITUATIONS VACANT AND WANTED.

MOULDERS (general) and Coremaker required immediately for Government Factory. Experienced men used to high class petrol motor work. Good wages and prospects, War bonus, and overtime. No man on Government work or eligible for Military Service will be engaged.—Write or apply in first instance to your nearest Board of Trade Employment Exchange, mentioning this paper and No. A2673.

WANTED, in Belgian Metallurgical Works, Good Draughtsman, experienced in installations, mechanical work.—Reply G. B. 40, Offices of *The Foundry Trade Journal*, 165, Strand, London, W.C.

FOUNDRY FOREMAN.—Wanted, a competent man, thoroughly experienced in modern methods and power moulding machines for producing large quantities of light grey iron expeditiously. Good organiser and firm manager of men. State age, experience, and wages required. Persons employed on Government work need not apply.—Apply your nearest Employment Exchange, mentioning No. A. 2681.

WANTED, for Birmingham District, Energetic Commercial Manager for Progressive Foundry. Must have had practical experience in LIGHT CASTINGS TRADE. Good salary paid to suitable man. When replying state experience, references, and wages required to Box 858, Offices of *The Foundry Trade Journal*. 165, Strand, London, W.C.

WANTED, Working Foreman Moulder, capable of taking control of small foundry in Leicester. State age, experience, and wages. Also two Moulders and Cupola man. No one on Government work will be engaged.—Address, Box 860, Offices of *The Foundry Trade Journal*, 165, Strand, London, W.C.

SUPERINTENDENT required for Copper Smelting and Non-ferrous Metal Refining Works, to assist Manager, take out working costs, conduct tests, etc. Good opening for man of scientific education, with works experience and organising ability.—Write, stating age, experience, and salary required, to Box 856, Offices of *The Foundry Trade Journal*, 165, Strand, London, W.C.

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SURPLUS PLANT FOR SALE.

ONE Patent Horizontal Sand Mixer, fitted with special oscillating cover, 2 grids, and 3 sets of beaters. Ball bearings to main shafts. Capacity 3 to 4 tons per hour. Complete with countershafts and belt striking gear. By the London Emery Works Company. In perfect condition, equal to new.

1 Flat Table Hydraulic Moulding Machine, table fitted with 4 lifting pins and arranged to take moulding boxes 50in. by 17½in. Complete with wooden rammer blocks to press head. By London Emery Works Company. Equal to new.

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42 Moulding Boxes, 50in. by 17½in., with planed faces.

2 Iron Pattern Frames for plaster blocks.

42 Moulding Boxes, 26in. by 21½in.

Also a quantity of hydraulic piping, ¾in. and 1½in., fitted with T connections.

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FOR SALE.—24-in. Invincible Sand Mixer, capacity 3 tons per hour, for grinding, mixing and screening foundry sands, at lowest cost per ton.—Apply, HALL, 26, Paradise Square, Sheffield.

FANS AND BLOWERS.—One No. 4 Roots' Blower and Engine combined, by Thwaites Bros. One Duplicate Fan Engine, by Haggie Bros., 18 in. by 18 in., also Guibal Fan, 20 ft. dia. by 8 ft. wide.—CUDWORTH & JOHNSON, Eagle Foundry, Wrexham.

12 IN. Roots' Blower, by Dempster, driven direct by horizontal steam engine; 8-in. ditto, by Thwaites, with vertical engine, self-contained; low price; immediate delivery.—WILLIAMS & SONS, South Bermondsey Railway Station, London, S.E.

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40-TON STEEL METAL LADLE, 8 ft. 6 in. dia., 8 ft. deep, firebrick lining, lifting shackles, etc., on portable railway, truck 4 ft. 8½ in. gauge, spare ladle and chains.

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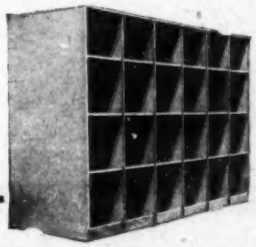

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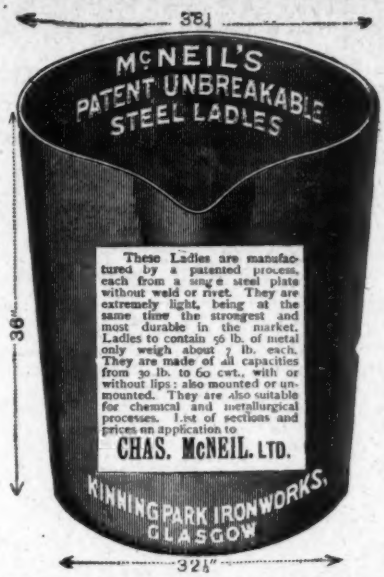
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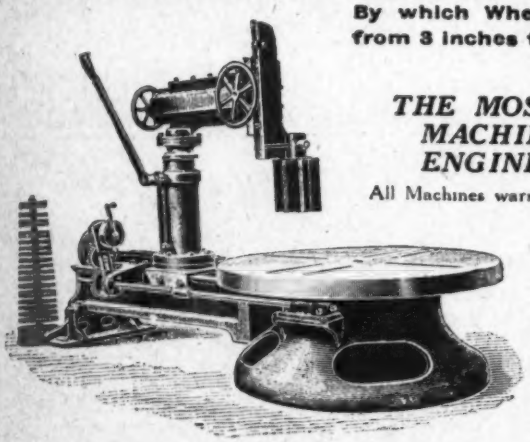

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PAGE.	NAME.	ADDRESS.	TELEGRAPHIC ADDRESS.	TELEPHONE NO.
	Adaptable Moulding Machine Co.	Stanhope Street, Birmingham	"Adaptable"	1966 Mid.
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C. iii.	Bradley, T. & I. & Sons, Ltd.	Darlaston	Bradley, Darlaston	—
107	Britannia Foundry Co.	Coventry	Stove-, oventry	251
62	British Binderit Co., Ltd.	Wharf Road, Wandsworth, S.W.	Bindercomp, Wands., London	994 Putney
C. ii.	British Thermit Co., Ltd.	49 & 51 The Albany, Liverpool.	Thermetal, Liverpool	1680 Central
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	Davies, T. & Son	West Gorton, Manchester	Tuyere, Manchester	70 Openshaw
109	Durrans, Jas. & Sons	Penistone, nr. Sheffield	Durrans, Penistone	21 Penistone
70 & 105	Evans, J. & Co.	Manchester	Ladles, Manchester	2397
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60	Gibbons, James	Wolverhampton	—	—
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66	Hall, John & Co. (Stourbridge), Ltd.	Fire Clay Works, Stourbridge	Hall, Stourbridge	55 Stourbridge
65	Hedley Moorwood & Co., Ltd.	21, Church Street, Sheffield	Morod, Sheffield	4318
	Hislop, R. & G.	Paisley	Gas, Paisley	331 Paisley
111	Hunt J. L. & Co.	56, 58, 60 Chapel St, Salford, Manchester	—	—
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C. i.	Macdonald, John, Ltd.	Waft Street, Maryhill, Glasgow.	"Compressor, Glasgow."	61 Maryhill (N)
111	Mansergh, T. E.	Wheathill Charcoal Works, Salford	—	—
	Marshall, H. P. & Co.	Leeds	Speciality, Leeds	1909 Leeds
	Metalline Cement Co.	112, Bath Street, Glasgow	Adhesive, Glasgow	201 Y2 Douglas
112	McNeil, Chas., Ltd.	Kinning Park, Glasgow	McNeil, Glasgow	X 155
	Midland Metal Co.	Coventry	—	—
57	Monometer Manufacturing Co., Ltd.	Whitehouse St., Aston, Birmingham	—	—
61	Naish & Croft	150, Alma Street, Birmingham	—	—
112	Olsen, William	Cogan Street, Hull	Wm. Olsen, Hull	Nat. 1184
C. iii.	Phillips, J. W. & C. J.	23, College Hill, E.C.	Colloquial, London	10112 Central
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59	Samuelson & Co., Ltd.	Banbury	Samuel on, Banbury	17 Banbury
111	Sankey, Joseph & Sons, Ltd.	Hadley, Salop	Sankey, Hadley	—
61	Stewart, D. & Co., Ltd.	London Road Iron Works, Glasgow	Stewart, Glasgow	71 P.O. Bridgton & 3243 Bridgton (N.)
66	Spermolin Core Co.	Spermolin, Halifax	Halifax	397
C. ii	Thermit Ltd.	675, Commercial Road, E.	Fulmen, Step, London	East 4157
	Tilghman's Patent Sand Blast Co., Ltd.	Broadheath, nr. Manchester	Tilghmans, Altrincham	14
6	Thwaites Bros., Ltd.	Bradford	Thwaites, Bradford	3456 & 3460 Brdf'd.
68	Universal Machinery Corporation, Ltd.	326, Old Street, London, E.C.	Toolcraft, London	3763 London Wall.
60	Universal System of Machinery Co.	97, Queen Victoria Street, London, E.C.	Machimould, London	4243 City
61	Walker, I. & I.	Rotherham	—	—
	Walco, Ltd.	53, Newton Street, Birmingham	Walco, Birmingham	Central 3305
113	Whittaker, W. & Sons, Ltd.	Oldham	Whittakers Engineers, Oldham	83
69	Wilkinson, Thos. & Co., Ltd.	Middlesbrough	Blacking, Middlesbro'	419
i	Williams, J. (Birmingham Sand), Ltd.	Birmingham	—	—

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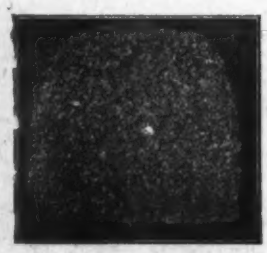
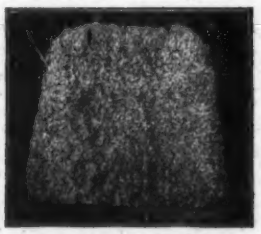
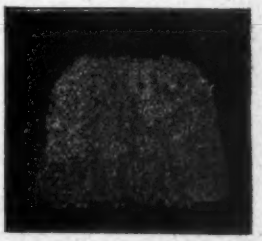

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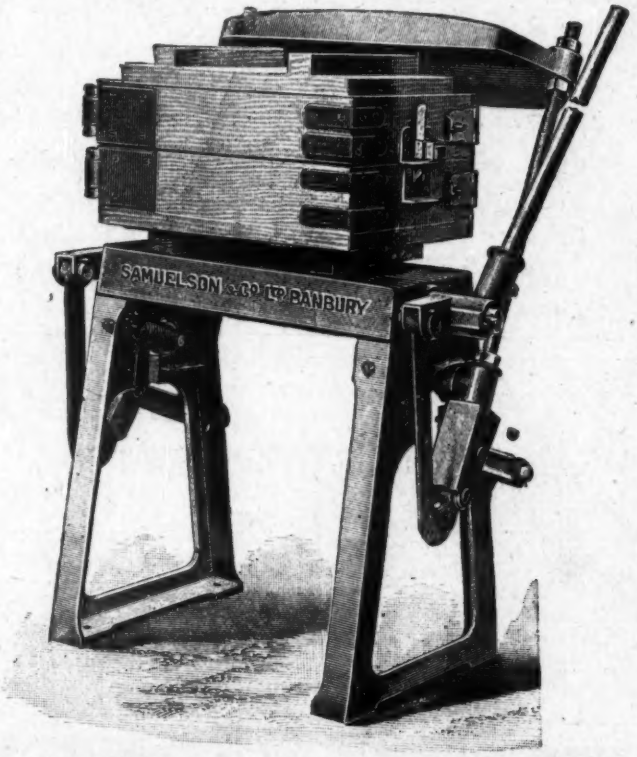

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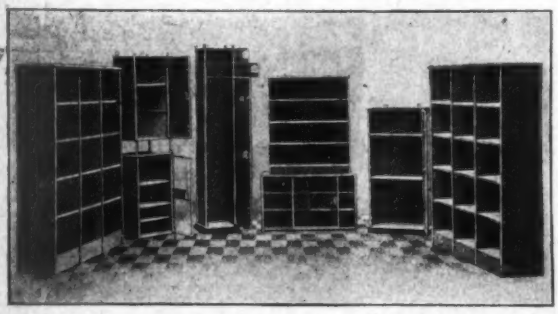

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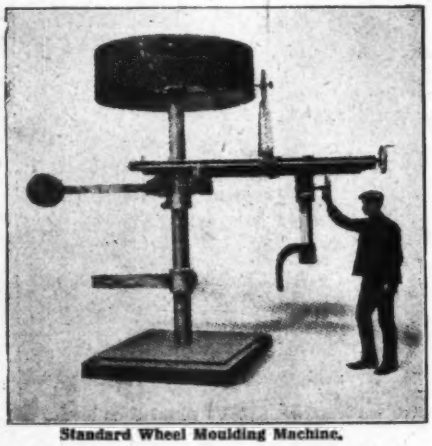

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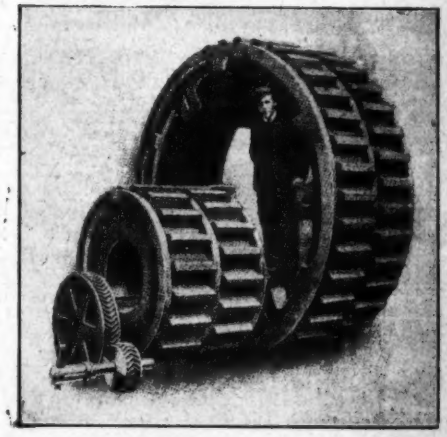

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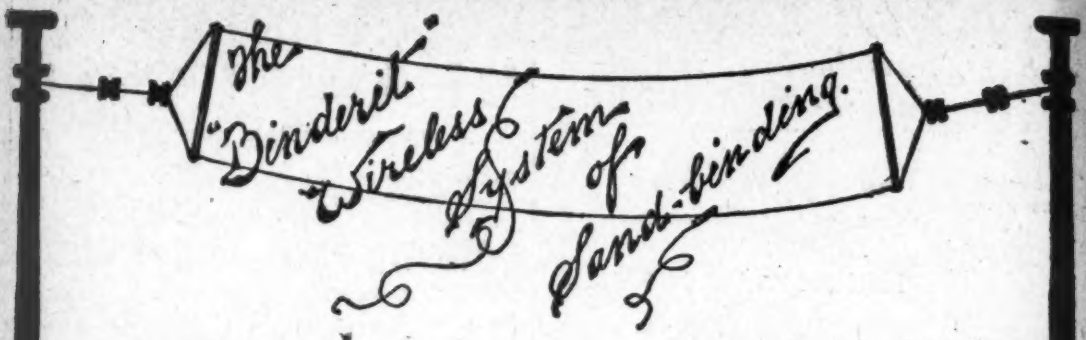

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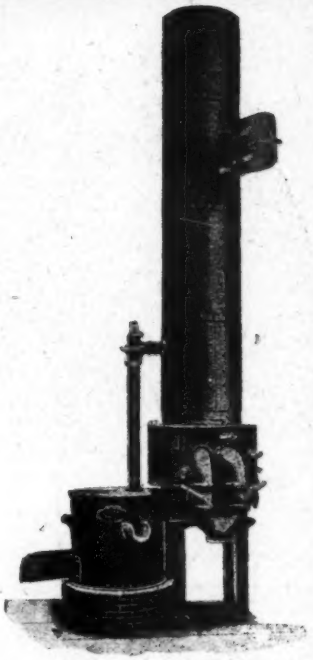

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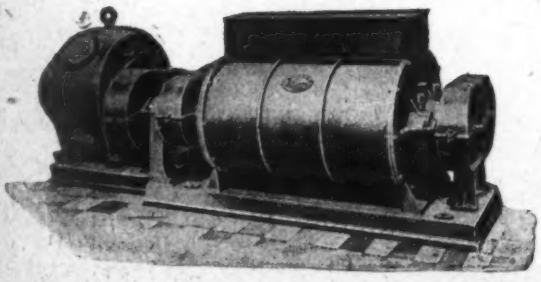

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